Control ENGINEERING

INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS

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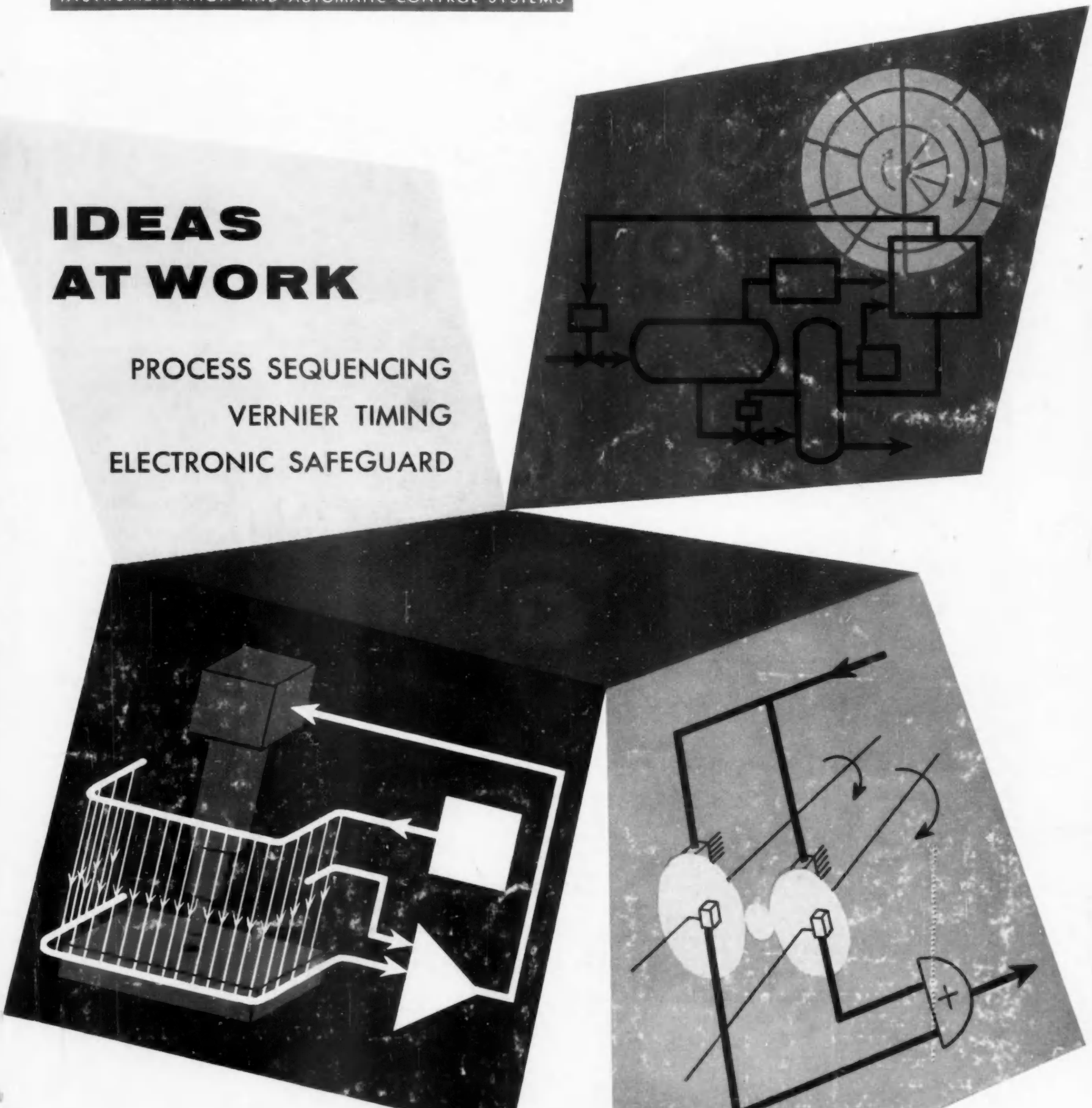

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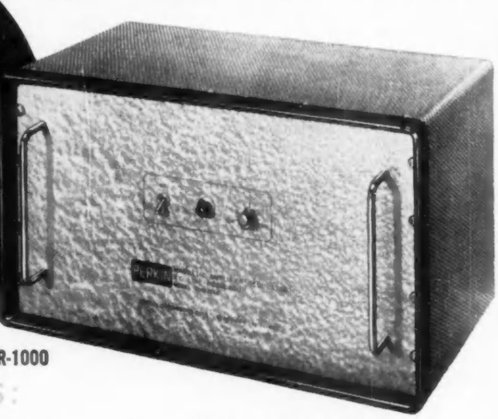

Model MLR-1000

SPECIFICATIONS:

Input voltage range: 95 to 135 volts

Output voltage: Nominal 115 volts, can be adjusted from 110 to 120 v.

Output current: 8.5 amperes

Frequency range: 60 cycles ±10%

Wave form distortion: 3% max.

Power factor range: 0.5 lagging to 0.9 leading

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Ambient temp. range: Up to 45° C

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Model	Volts	Amps	Reg.	AC Input (60 cps)	Ripple rms
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28-10WX	24-32 V	10	±½%	100-125 V 1 phase	1%
MR532-15A	2-36 V	15	±½%	105-125 V 1 phase	1%
28-15VFM	0-32 V	15	20% (24-32 V range)	115 V 1 phase	5%
M60V	0-32 V	25	±1%	115 V 1 phase	1%
MR1040-30A	5-40 V	30	±1%	100-130 V 1 phase	1%
28-30WXM	24-32 V	30	±½%	100-125 V 1 phase	1%
28-50WX	24-32 V	50	±½%	230 V* 3 phase	1%
MR2432-100XA	24-32 V	100	±½%	208, 230, 460 V ±10% 3 phase	1%
MR2432-200	24-32 V	200	±½%	230 V* 3 phase	1%
MR2432-300	24-32 V	300	±½%	230 V* 3 phase	1%
MR2432-500	24-32 V	500	±½%	230 V* 3 phase	1%

*±10%. Also available in 460 V ± 10% AC input. Will be supplied with 230 V input unless otherwise specified.

6, 12, 115 VOLT DC POWER SUPPLIES:

	Model	Volts	Amps	Reg.	AC Input (60 cps)	Ripple rms
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	6-15WX	6 ±10%	15	±1%	95-130 V 1 phase	1%
	6-40WX	6 ±10%	40	±1%	95-130 V 1 phase	1%
12 Volt	12-15WX	12 ±10%	15	±1%	95-130 V 1 phase	1%
115 Volt	115-5WX	115 ±10%	5	±½%	95-130 V 1 phase	1%
	MR15125-5	15-125	5	±1%†	95-130 V 1 phase	1%†
	G125-25**	115-125	25	1½-4%	230/460 V 3 phase	5%

**Germanium Rectifier Unit †Increases to 2% @ 15 V.

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Control ENGINEERING

FEBRUARY 1957
VOLUME 4 NUMBER 2

INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS
Published for engineers and technical management men who are responsible for the design and application of instrumentation and automatic control systems.

TABLE OF CONTENTS

Continued on next page

Control ENGINEERING

Continued from the preceding page

Vacations, babies, teeth, sick aunts . . . we have 'em too. When Managing Editor Lloyd Slater laid down a dictum on this subject last September he must have been planning for his New Year's vacation on Grand Cayman, B.W.I. He named Harry Karp to tend shop for him. Harry finished his editing of articles for the March issue and then stepped in to manage the February issue. He has done a commendable scheduling job – he not only kept us on schedule, but kept his family on schedule too, for on Dec. 18 he became a papa for the first time. It's a boy!

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Society participation?

Many of the problems that arise in putting out a magazine serving a technical field are very similar to those facing the managements of user and maker companies in that same field. A case in point is staff participation in professional societies. In the control field this problem becomes particularly pressing—many different societies and committees claim time and talents. Which societies should our men join? How much time and effort should they devote to committees?

Three reasons why

CONTROL ENGINEERING assayed its own situation in this respect to formulate a policy. At a CtE get-together, McGraw-Hill's director of special editorial activities, L. C. Morrow, listed for our staff eight good reasons why CtE should contribute the time and talents of its men to professional societies. Three of these apply to most industrial companies we serve:

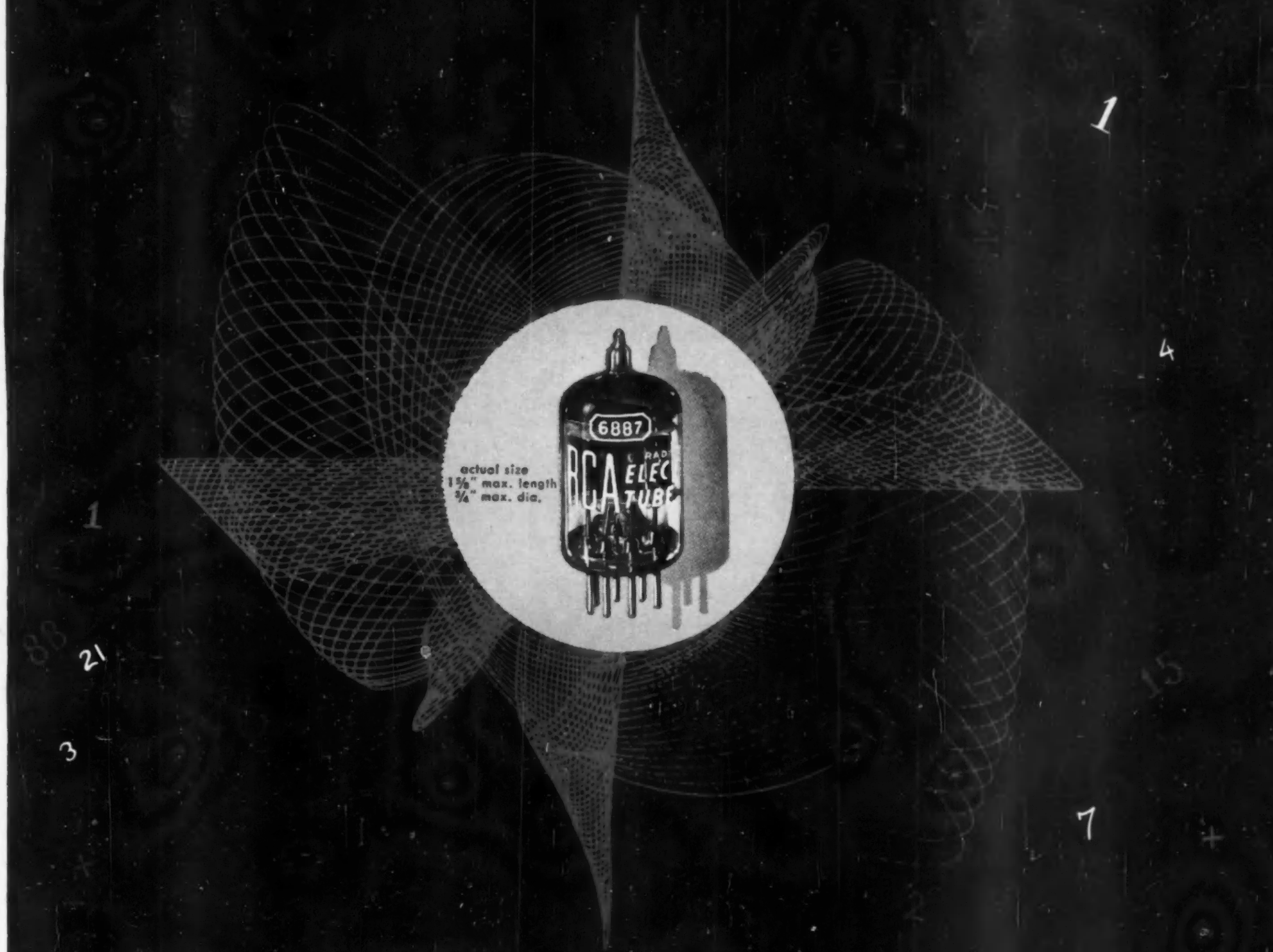
1. Our field is new and growing.
2. It is close-knit, thus simplifying cooperative efforts and interchange of information.
3. The professional level of the front-line and supporting staff determines the amount of time that can be spent in extracurricular work without interfering with the main task of getting out a product.

CtE society activities

Next, we reviewed what the editorial staff was doing to carry out its responsibilities. We found that most editors had been engaged in some technical group work even before joining the CtE staff:

William E. Vannah—member ISA, ASME; secretary of ASME/IRD, '56; technical program chairman IRD conference, '58; temporary secretary of North American Council of International Federation of Control Systems Engineering.
Byron K. Ledgerwood—member AIEE, ASME, NSPE; AIEE Feedback Controls Committee; AIEE Machine Tool Control Committee.
Lloyd E. Slater—member ISA; program chairman Fairfield (Conn.) ISA; publicity chairman 11th International ISA Conference.
Harry R. Karp—member AIEE, ISA; editor Dynamic Systems Committee (IRD); education and employment chairman N. J. ISA; publicity chairman for IRD.
Edward J. Kompass—member IRE, ISA.
Frank X. McPartland—student member ASME.

Comments from the staff while this list was being collated indicated that their enthusiasm and efforts resulted more from their personal and professional engineering interests than from their work as editors. Bill Vannah summed up our policy by stating that CtE will give basic editorial support to any society that serves its readers, and that we'll not only continue our present efforts but will try to do more.



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For technical data on RCA-6887, write RCA Commercial Engineering, Section B56Q, Harrison, N. J.

FEEDBACK

Scrounge boxes can inspire

To the Editor—

An idea came to me re the engineer shortage at a recent meeting of our elementary school PTA. The program concerned the teaching of science in the schools. It seems one of the main difficulties the teachers had in interesting the students in science was in obtaining suitable equipment. Even such ordinary things as wire, transformers, switches, etc., are hard to come by.

Every electrical engineer I know has a scrounge box of miscellaneous parts and odds and ends around his home. Why not contact your local school to see if any of them could be put to good use? And your voluntary service in helping the teacher devise working models and display units might provide just the necessary inspiration for some talented youngster to take up science or engineering for a career.

Robert Fauvre
Northbridge, Calif.

Specifying dynamic performance

To the Editor—

This letter describes the work being done by the AIEE Feedback Control Systems Subcommittee on Definitions, Symbolisms, & Specifications. Because of your readers' interests in allied subjects, I feel that this information will be of benefit to them.

Broader knowledge of the activities of the Feedback Control Systems Components Subcommittee throughout the control systems field should encourage systems and component designers to a more ready acceptance of the idea of specifying dynamic performance of control system components.

The Components Specifications Subcommittee has sought to build on the definitions, letter symbols, and block diagram ideas of ASA Y10.13-195 by extending those concepts which are pertinent into the specifications of various feedback control system components. For preliminary purposes, the control system components have been divided into such generic categories as signal elements, amplifiers, and power elements.

The subcommittee's objectives:

1. For each component, the sub-

(*Continued on page 14*)

FORUM . . .

To the Editor—

Anent "*Industry's Pulse*—How Do the Users View Electronic Control?" in the November issue.

One major reason for the slow rate of acceptance of electronic controls by users in the process industries may be lack of standardization of signals. One manufacturer uses a 0-0.5-volt ac signal for process measurement and a 4.00-8.00-ma dc signal for the controller output. Another uses 0.5-5.0-ma dc for measurement and control output. Other manufacturers who are presently developing this type of equipment expect to use still other ranges for their signals. Obviously, the makes of equipment now available are not compatible with each other and neither may be compatible with equipment manufactured to the standard signal range which is sure to be established.

It seems to me that the manufacturers could save themselves considerable sums of money by getting together now and establishing a standard. Furthermore, establishment of a standard signal range would enlarge the market by removing the user's fear that he is tied to one source of supply and to a type of equipment which may soon be obsolete.

C. A. Prior
Cleveland, Ohio

SAMA replies to reader's prod.

The Scientific Apparatus Makers Association Recorder-Controller Section's Subcommittee 13-D has just completed a study of manufacturers' preferences for standards in ac and dc measurement and control transmission signals. In surveying manufacturers on preferred standards, the subcommittee sought a simple structure for fundamental standards. The questionnaire considered only systems involving continuously variable electric signals of potential or current proportional to measured quantities. This excluded pulse- and frequency-modulated systems used in long-distance transmission as well as feedback signals from the final control element (valve operator, for example).

The subcommittee adopted these definitions:

▶ absolute signal system, one in which the transmitted signal is a function of the measured quantity (or retrans-

mitted function) and is independent of system supply voltage; example—force-balance type;

► relative signal system, one in which the transmitted signal is proportional to supply voltage as well as to the measured quantity; examples—resistance potentiometers and differential transformers.

Specific system standards listed in the questionnaire:

1. dc current—inherently two-conductor absolute systems

Output current (ma)	1–5	10–50	0 ± 1/2
Load resistance ohms (maximum)*	5,000	500	10,000

2. ac voltage—two-conductor relative systems with fixed phase

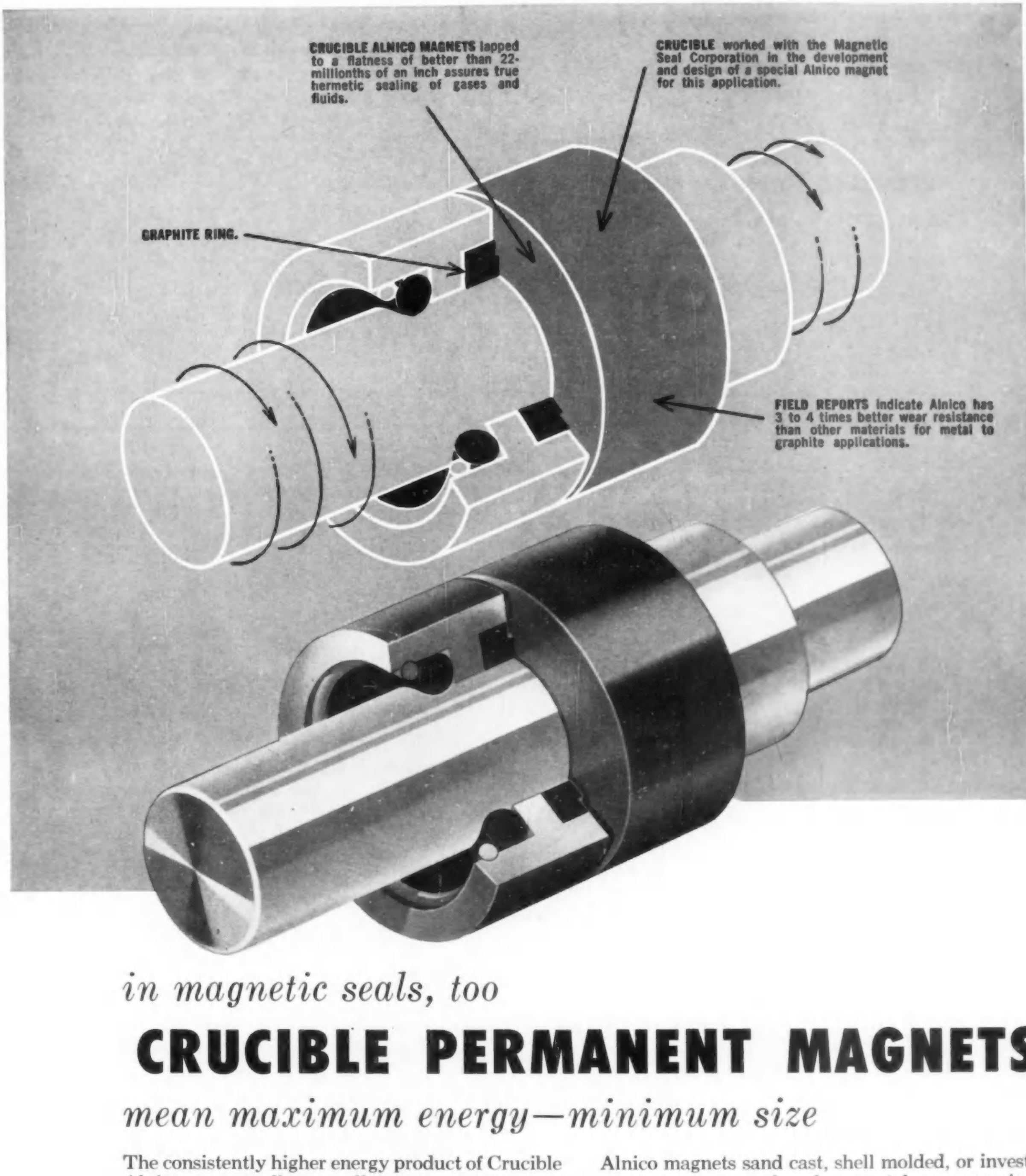
*Supply volts (nominal) frequency	120 60	120 60	120 60	120 60	120 60
Output volts frequency	0–0.5 60	0–5.0 60	0 ± 2½ 60	0 ± 120 60	0–35 60
Load impedance ohms (minimum)	1/2 meg	1/2 meg	600 (fixed)	variable	5,000 (min)

* Note–This is the system supply voltage and not necessarily the actual voltage applied to the transducer which may be supplied through a transformer.

Tabulation of preferences of participants in SAMA Recorder-Controller Section's Questionnaire on signals for electric transmission and control

PREFERRED STANDARDS

COMPANY	DC CURRENT		AC VOLTAGE				Phase Angle	Will Use Std
			Supply					
	Signal ma	Load Ohms	Volts	Freq	Signal Volts	Load Ohms		
Applied Science Corp. of Princeton	0–1	10000	120	60	0–5.0	1/2 meg		Yes
Askania Regulator Co.	1–5 10–50	5000 500	120 120 120	60 60 60	0–1/2 0 ± 120 0 ± 40	1/2 meg Variable 0.1 meg	0°	Yes
Automatic Temperature Control Co.	1–5	5000	120	60	0–1/2	1/2 meg	90°	Yes
			Do not think we should limit future developments by premature standards.					
Bailey Meter Co.			120	60	0–5.0	10000	+30°	Yes*
			*This is qualified depending on the cost and complexity of modifications. Suggests dc voltage system be included.					
Barber-Colman Co.	1–5	5000	120	60	0–1/2	1/2 meg		Yes
			Believes it possible to standardize frequency modulated systems now.					
Beckman Instruments	0–5	1000		60	0–1/2	20K	0	Yes
Bristol			120	60	0–1/2	1/2 meg	58°	Yes
			Feels that standard should permit inclusion of other signal systems such as pulse and frequency.					



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FEEDBACK

PREFERRED STANDARDS (CONTINUED)

COMPANY	DC CURRENT Signal ma	DC CURRENT Load Ohms	AC VOLTAGE Supply Volts	AC VOLTAGE Supply Freq	AC VOLTAGE Signal Volts	AC VOLTAGE Load Ohms	Phase Angle	Will Use Std
Fischer & Porter	1-5 0±1/2	5000 10000	120 120	60 60	0-1/2 0±2 1/2	1/2 meg 600	90°	Yes
			Proposes ac current and variable frequency.					
Foxboro Co.	10-50	500	120	60	0±2 1/2	600	*	Yes
			*Devices potentially applicable to transmission signal use will probably have a leading angle; not yet determined, but will probably be less than 45 deg.					
Hagan Corp.	0-60	500	120	400	0±50			Yes
			Suggest ±50 vdc ± 5 vdc be included in proposed standard.					
Manning, Maxwell & Moore, Inc.	1-5 10-50 5-25	5000 500 1000						Yes
Mason-Neilan Regulator Co.	10-50	500						Yes
Metrotype Corp.	1-10	10000	120	60	0-5.0	5000	0	Yes
Minneapolis-Honeywell	4-20	600	Would consider standard in new designs.					
Panellit, Inc.	10-50	500	120	60	10-110	10000 min		Yes
			ac voltage should NOT: a. operate at low voltage b. have zero volts at lower limits Proposes dc voltage: a. 10-110 vdc, 10,000 ohm min b. 1-11 vdc, 1000 ohm min					
Powers Regulator	10-50	500						
Raytheon Mfg Co.	10-50	500	120	60			30°	Yes
Republic Flow Meter Co.	0-5	5000	120	60	0-35	5000	0±4°	Yes
			Will adopt if standard permits adequate coverage of field requirements.					
Simplex Valve & Meter Co.			Since pulse (time current) is excluded and we work principally in this form; both ac and dc interest limited.					
The Swartwout Co.	1-5	5000	120	60	0-1/2	1/2 meg	58°	Yes
Taylor Inst. Cos.	1-6	5000	120	60	0±1/8	1/2 meg	70°	Yes
Weston Electric Instrument Corp.	0±1/2 0-1	10000 5000						Yes
			Suggests pulse time ratio be included in the proposed standard.					

(*Continued from page 10*)

committee should add to and consolidate existing specifications to indicate the dynamic and other characteristics which the system designer needs.

2. If there are no existing specifications on a given component, the subcommittee should work with the appropriate technical committee to prepare these specifications.

3. The methods for testing a com-

ponent, where feasible, should be indicated by the subcommittee so that the desired characteristics are properly obtained.

4. The subcommittee should endeavor to educate both the system designer and the component designer as to the information required for component specifications.

Currently the Components Subcommittee is subdivided into small groups which are working on specific components:

Synchros

L. F. Kazda, Dept. of Electrical Engineering, University of Michigan, Ann Arbor, Mich.; M. Goldberg, Naval Department, BuOrd Code RES4D, Washington 25, D. C.

Gyros

P. Spink, Westinghouse Electric Corp., Friendship International Airport, Baltimore 27, Md., Robert Keeler, Minneapolis-Honeywell, Aero Div., Minneapolis, Minn.

Two-phase servo motors

T. A. Westover, Servo Corp. of America, 2020 Jericho Turnpike, New Hyde Park, N. Y.; W. D. Jefferson, John Oster Mfg. Co., One Maine St., Racine, Wis.

DC motors

R. G. Beadle, General Electric Co., Systems Application Engineering, Schenectady, N. Y.; L. F. Stringer, Westinghouse Electric Corp., Metal Working Section, Pittsburgh, Pa.

Transformers and magnetic amplifiers

D. D. Pidhayny and H. C. Trueblood, The Ramo-Wooldridge Corp., 5730 Arbor Vitae, Los Angeles, Calif.

Hydraulic components

E. S. Sherrard, Bureau of Standards, U. S. Dept. of Commerce, Washington 25, D. C.; D. C. Morin, Blackhawk Mfg. Co., Industrial Hydraulic Control, Milwaukee, Wis.; Warren Gaines, General Electric Co., Aircraft Products Dept., One River Rd., Schenectady, N. Y.; Andrew A. Seleno, Vickers, Inc., Administrative & Engineering Center, Detroit 32, Mich.

Potentiometers and pick-offs

C. W. Miller, Perkin-Elmer Corp., Engineering & Optical Div., Norwalk, Conn.; J. A. Mitchell, Hughes Aircraft Co., Weapons Systems Development Laboratory, Culver City, Calif.

Accelerometers, integrators, and precision power supplies

A. Paternini, Bell Aircraft Corp., P. O. Box No. 1, Buffalo 5, N. Y.

FEEDBACK

Analog-digital and digital-analog devices
C. H. Baldwin, Westinghouse Electric Corp., Youngwood, Pa.

Comments and suggestions for making the work of the subcommittee more effective to systems designers and component manufacturers will be welcomed by the subcommittee and should be addressed to Harold Chestnut, General Electric Co., One River Rd., Schenectady, N. Y. Information relating to the work being done on specific elements should be directed to the individuals working on the specific components.

Harold Chestnut, Chairman,
Components Subcommittee

Use less graph paper

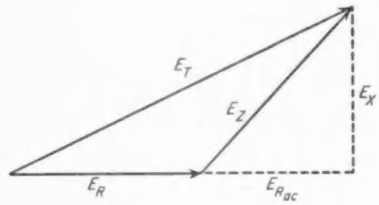
To the Editor—

In the August 1956 issue of Control Engineering an article by E. S. Shepard Jr. entitled "Simple Wide-Band Impedance Measurements" appeared. In this article Mr. Shepard discussed the use of vector diagrams and curve drawing to determine the resistance, R_{ac}, and reactance, X, of an unknown impedance. This method is very useful when only two or three readings are required and the phase angle of the unknown impedance is greater than 30 deg. However, if the phase angle is much less, the method progressively becomes more susceptible to error in drawing the curves and determining their intersection. Also, if a great many readings are needed, the method becomes extremely laborious and graph paper is used at a terrific rate, although this is not a serious drawback.

Repeated here for reference, Mr. Shepard's Figure 1 demonstrates that

$$|Z_T| = \frac{E_T}{E_R} R_s, \quad |Z| = \frac{E_z}{E_R} R_s$$

Redrawing the vector diagram in terms of the measured voltage readings is the first step in evolving a set of equations for calculating the resistance and the reactance of the unknown impedance:



From this voltage diagram,

$$E_T^2 = E_X^2 + (E_R + E_{Rac})^2, \tag{1}$$

and

$$E_X^2 = E_z^2 - E_{Rac}^2 \tag{2}$$

Substituting (2) into (1),

$$E_T^2 = E_z^2 - E_{Rac}^2 + (E_R + E_{Rac})^2 \tag{3}$$

which upon simplification and solving for E_{Rac} becomes

$$E_{Rac} = \frac{E_T^2 - E_z^2 - E_R^2}{2E_R}. \tag{4}$$

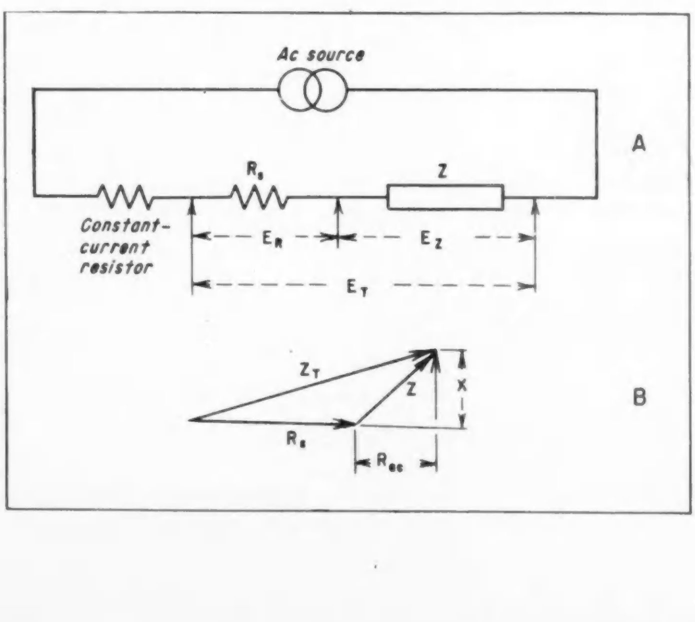
However, it is now possible to say that

$$E_{Rac} = \frac{R_{ac}}{R_s} E_R \tag{5}$$

Substituting (5) into (4) and solving for the unknown R_{ac}, we obtain,

$$R_{ac} = \frac{R_s}{2} \frac{E_T^2 - E_z^2 - E_R^2}{E_R^2} \tag{6}$$

If we use Mr. Shepard's advice and set E_R to a value of 1.0 volts, this expression for R_{ac} becomes



FEEDBACK

$$R_{ac} = \frac{R_s}{2}(E_T^2 - E_z^2 - 1) \qquad (7)$$

Also

$$|z| = E_z R_s$$

and

$$X^2 = z^2 - R_{ac}^2 \qquad (8)$$

then

$$X^2 = E_z^2 R_s^2 - R_{ac}^2 \qquad (9)$$

and

$$X^2 = E_z^2 R_s^2 - \frac{R_s}{2}[E_T^2 - E_z^2 - 1] \qquad (10)$$

The overall accuracy is mainly dependent on the accuracy of the voltmeter used. However, if the unknown resistance and reactance are only required to an accuracy of 3 or 4 percent, a slide rule will perform these calculations very nicely. Although these equations seem rather involved only the same data are required as in Mr. Shepard's method.

H. Havlicek Jr.
Schenectady, N. Y.

Market within the market

To the Editor—

We are looking for a zero speed tachometer pickup for use in the continuous process industries. The device must be capable of producing a number of electrical pulses proportional to input speed over the range from zero to 3,000 rpm. Extreme reliability is important because of the high cost of down time in a continuous industrial process. There are no unusual environmental hazards other than dust and dirt and the possibility that explosion-proofing may be required in some applications.

Robert P. Einsel
Industrial Nucleonics
Columbus, Ohio

Latch on to the affirmative

To the Editor—

In the section on Safety Control on page 76 of my article entitled "Controlling a Nuclear-Driven Gas-Cooled Reactor" in the October issue of Control Engineering the following misleading statement appears: "The scram condition is a last resort and should not be used when the safety of the reactor or operating personnel is at stake." The word "not" should, of course, be "only" to make the sentence read correctly.

Milton Lowenstein
New York, N. Y.

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A Complete and Flexible Core Testing System

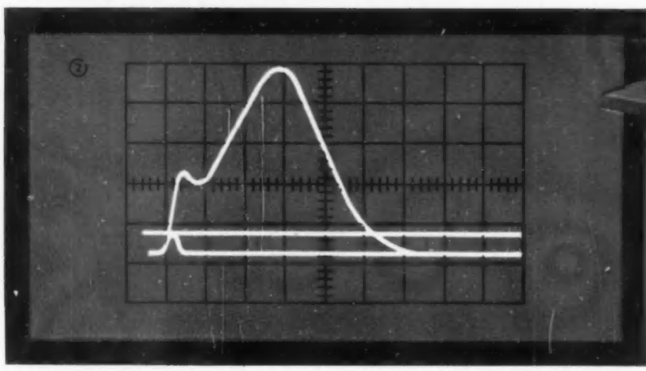
The BCT-301 has been designed expressly for the individual testing of square loop cores. It provides precise control over the frequency, pattern, amplitude and rise time of the core driving signal, and allows extremely accurate measurements of the switching time of the core, as well as the amplitude of the output pulse. The unit is composed of five basic sections, each of which can be replaced or expanded for other types of core testing.

Core Mounting Jig This low-noise test mounting jig applies tight single turn loops around the core for input and output windings. It has been designed to minimize not only pickup by the secondary, but also other disturbances caused by air flux. Adjustable pins accommodate a wide range of bobbin sizes with equal precision.

Pattern Generator The Pattern Generator provides extreme flexibility in generating the pulse patterns which are applied to the core. This section of the system controls the pulse spacing, repetition rate of the cycle, and the number of pulses in the pattern.

Current Drivers Two Current drivers convert the voltages from the pattern generator into the positive and negative constant current pulses used for driving the core.
Front panel controls provide:

- Variable current amplitude from 0 to 1.0 ampere
- Variable rise time from 0.2 μsec. to 1.0 μsec.
- Variable pulse duration from 1.0 μsec. to 10.0 μsec.



Calibrator The calibrator is designed to accurately measure currents and voltages. It permits the measurement of both the driving current and the amplitude of the output voltage with an error of less than 1%. When used with a calibrated oscilloscope, it makes possible highly accurate readings of switching time.

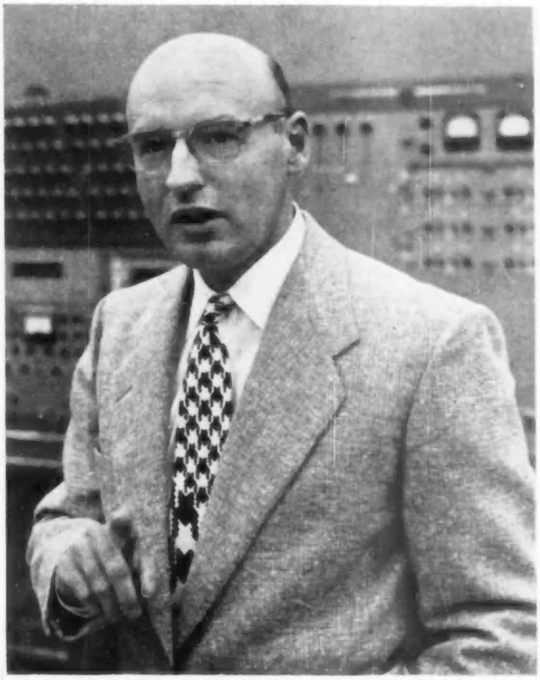
Power Supply The power supply provides seven regulated d-c voltages.

GENE GRABBE **tramples on tradition**

Back in 1949 there was good reason to discourage the idea of an airborne digital computer. After all, even without thinking about size, how many electronic digital computers were in existence and operation then? One, maybe two. And since size had to be a factor, could these existing computers fit into a plane's innards? Not if their 5,000 to 10,000 tubes and 50-to-100 kw of power supply had to go in, too, and they most certainly would have to. So it was understandable, when a group of outside engineers visited a Hughes development team in its laboratory eight years ago, that they would tell Group Leader Gene Grabbe that the proposed computer, small enough to be simply another component in a military system, would never get off the ground.

But Grabbe's team had already evaluated the alternate lines of action possible for its Digitac System, and on the basis of an analysis of this evaluation, uncluttered by "traditional" engineering and physics, it had made its decision. The computer, carrying a dainty load of a few hundred tubes backed up by the then-new germanium diodes and the laboratory's own analog-digital converters, did get off the ground. And with it soared Gene Grabbe's personal engineering philosophy. These days he expresses it this way: "We need more people with training and experience that cuts across traditional lines of activity. In examining my present activities, it appears to me that a great part of my effort is devoted to breaking down barriers and speeding interchange of information."

Early in 1954, Dr. Eugene M. Grabbe joined the newly formed Ramo-Wooldridge Corp. Today, as senior staff consultant on automation in the Computer Systems Div., he consults with other divisions of the company on computer matters, works with the company-wide Automation Steering Committee, and in many other ways exercises his great interest in digital computers and their application to control problems. Outside R-W, he averages several speeches each month on computers, business data processing, and automation developments, helps steer the Professional Group on Automatic Control as vice-chairman of its National Administrative Committee (he organized the Los Angeles chapter), acts as a consultant to CONTROL ENGINEERING, and lectures at UCLA on "Automation in Business and Industry". He is preparing these lectures, which are based on material furnished by 21 authorities on control engineering, for publication in March by John Wiley & Sons, Inc. He is also working, with Simon Ramo and Dean Wooldridge, on another Wiley book, this one a three-volume "Handbook of Automation, Computation, and Control".



Beloved computers form background for Grabbe lecture.

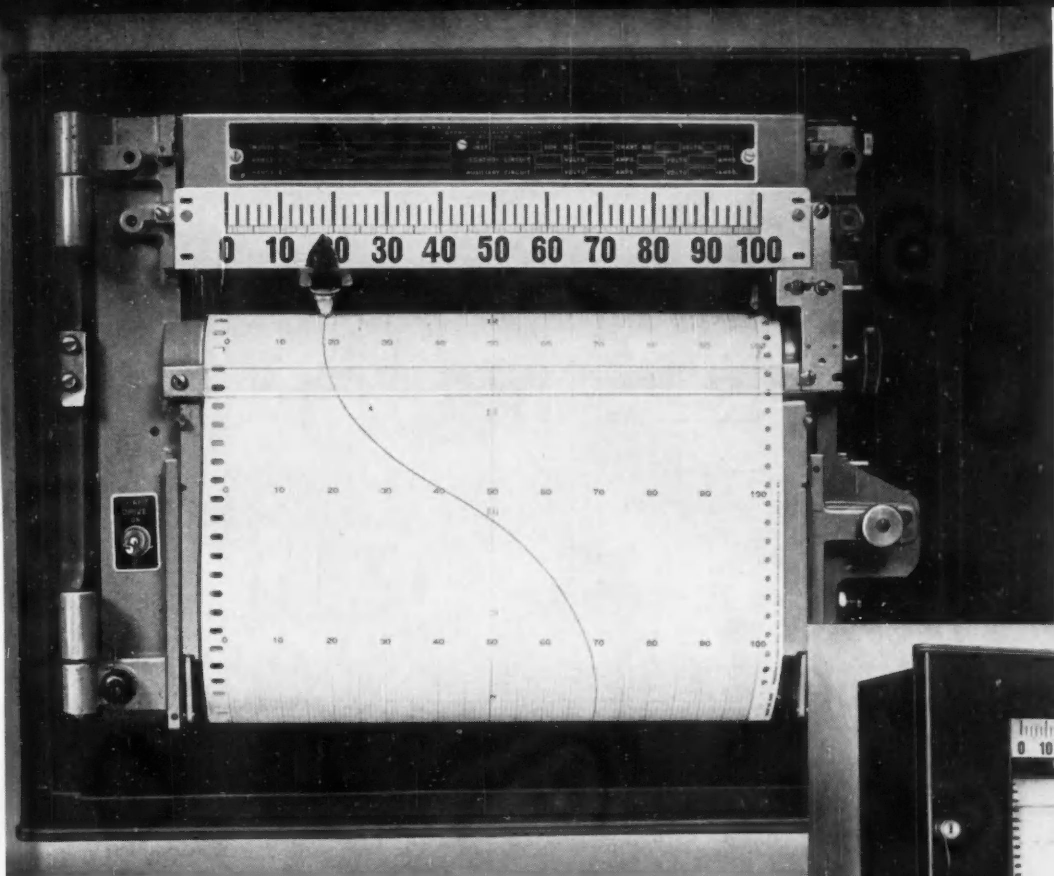
Grabbe spent the 1930's getting his formal education, which began in 1931 with the study of chemistry and mathematics at the University of Pittsburgh in his home state of Pennsylvania (he was born in Johnstown in 1912), and ended in 1939 with a PhD in physics from Yale. In between he earned a BS in mathematics from Duke (1935) and an MS in physics from Brown (1937). His first post-PhD job was with U. S. Rubber as a research physicist and group leader, his second with Homelite Corp. as a technical consultant. From there he went to Hughes Aircraft.

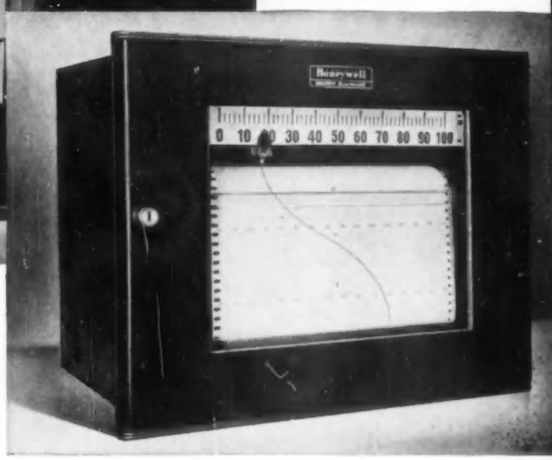
Gene is a beekeeper, a photographer, a hi-fi enthusiast, a surf-fisherman, and a quiz-show (You Bet Your Life) contestant (CtE, May '56, p. 4). These activities, most of which are shared in by his wife Arien and their four children, Willow 12, Linda Louise 10, Ann Elizabeth 7, and John Peter 1, take place either at their home in La Canada, Calif. or their beach house in La Mision, Baja California, Mexico, 40 miles south of the border.

New
¼-second
Electronik recorder
follows fast-changing variables with

Outstanding new features:

- Simplified design
- Improved damping
- High input impedance
- Continuous standardization





● **REFERENCE DATA:** Write for Instrument Data Sheet No. 10.0-21, "¼-Second Pen Speed *ElectroniK* Recorder."

split-second response

DESIGNED to meet the special data-recording requirements of experimental stations, laboratories, and research centers, the new ¼-Second Pen Speed *ElectroniK* Recorder fills an important gap between conventional large-chart recorders and oscillographic instruments.

This new *ElectroniK* Recorder is the *fastest* large-chart instrument available today . . . the perfect solution for high-speed plotting of any function that can be reduced to a d-c millivolt signal. It offers the investigator extreme sensitivity, complete flexibility, laboratory precision . . . the *basic* plus features of advanced Honeywell design. In addition, the recorder incorporates many *new* features the research man will appreciate:

Easy range change—All components of the potentiometer bridge are located on one bakelite card. To change the range, merely put in the appropriate card.

New design plug-in amplifier—has many times the power output of standard units . . . features high input impedance, easy accessibility, flexible gain control, and rugged construction.

New pen and carriage designs—prevent pen clogging and paper tearing. Ball point pen easily removed. Transparent cartridge gives visual indication of ink supply.

New slidewire and contacts—Designed for long life under high speed operation.

Your nearby Honeywell sales engineer will be glad to discuss ways in which you can benefit from the new ¼-Second *ElectroniK* Recorder in your research work. Give him a call . . . he's as near as your phone.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, Wayne and Windrim Avenues, Philadelphia 44, Pa.—in Canada, Toronto 17, Ontario.

H HONEYWELL

MINNEAPOLIS
Honeywell
BROWN INSTRUMENTS

First in Controls

Watchdog Patman Hears Feedback . . .

from:
- industry
- labor
- schools
- government

. . . On Dangers of Technical Recession

Testifying on Dec. 12, 13, and 14 before Rep. Wright Patman, chairman of the Joint Economic Committee's Subcommittee on Economic Stabilization, educators, instrument users, and instrument manufacturers contended that measurement and control practice, far from replacing labor, is an absolute necessity if the available labor-time, expected to increase only 5 percent by 1965, is to carry the required 37 percent increase in productivity by then. The manufacturers pointed out that while they have a potential bonanza in the resulting multiplication of markets for their products and services, they may not realize the potential unless technical manpower for applying and maintaining their products is developed quickly and thoroughly.

Cures proposed by witnesses included a government task force to study the problem, increased tax deductions for tuition and contributions for technical training, a control engineering extension service, a centralized literature retrieval service at the National Bureau of Standards, in-service training of draftees (to take a cue from Russia), and tax breaks for the small manufacturer of instruments.

Dr. Elmer C. Easton, dean of the College of Engineering, Rutgers University, explained that during the next ten years a relatively small percentage of workers must support a much larger percentage of children and elderly retired people. This will require increased productivity, the key to which is improved materials conversion by automatic machines. Because the design and application of the automatic equipment calls for control engineers well versed in analysis, design, and systems integration, readers will welcome Easton's report that accrediting of engineering colleges has recently focused on their ability to "impart competence in engineering analysis, design, and systems". Even though dissatisfied with the way students are prepared for engineering colleges, he lauded the Engineering Manpower Commission, the Edison Foundation, and the American Association for the Advancement of Science, all effective in increasing college output from 19,700 in 1954 to 25,500 in 1956, and to a probable 30,500 in 1957.

"But," he added, "assuming that the colleges will produce the needed engineers, every precaution must be taken to utilize these men effectively —for creative engineering design." He suggested that the engineer intern to get his industrial experience and that when subsequently admitted to full engineering status he "be aided by technicians just as the physician is aided by nurses". Setting a short-term goal of three technicians per engineer, he recommended "that the campaigns which have been so successful in producing interest in engineering now be turned to the technician". (See page 18, Dec. '56 issue of CONTROL ENGINEERING for additional discussion of the ratio.)

Feedback for the entrepreneur

A switch from technical manpower lacks to technical practice came with the testimony of A. F. Sperry, president of Panellit, Inc., who described mechanization as an extension of human muscles, instrumentation as an extension of human senses, and systems engineering and data processing as extensions of mental capa-

Systems Entrepreneur A. F. Sperry (left) tells R. T. Sheen (center) and Rep. Wright Patman that "the labor organizations with whom we have been involved have helped us to solve labor problems as they came up, without raising any roadblocks".

Shortening Time Scales in Feedback Loop Improves Plant Control

	(1) Automatic controllers	(2) Operators	(3) Technical staff	(4) Management
Prewar (1920-1940)	Sec—Min	Min—Hrs	Days—Weeks	Weeks—Months
Postwar (1945-1954)	....	Sec—Min Hrs	....	....
Today (1955-1960)	....	Sec—Min	Hrs—Days	Days—Weeks
Future (1960 —)	Split Sec	....	Hrs	Days

bilities such as memory, mathematical manipulation, comparison, and decision-making. He noted that "maintenance costs are averaging about twice as high as direct labor, so it hardly seems as though a 'second industrial revolution' could result from further savings in manpower". Economics lie in truly effective control of plants in which material and energy conversion losses are greater than direct-labor cost. He described four echelons of feedback: plant management, technical operation, unit operation, and labor or (currently) automatic control. With the table he demonstrated to what extent the time scales of the four echelons of feedback have decreased since the pre-World-War-II period. The systems engineer, who will articulate the four echelons, must, contended Sperry, "have enough creative imagination to hurdle the roadblocks of tradition and, yet have the inate conservatism to draw on the experience of the past . . . to carry out his mission, design, build, buy, erect, and operate his project.

"This is a pretty good description of the successful entrepreneur of American industry, and describes quite well the men who pioneered the industrial enterprises that made us the great power of the world. Now, however, industry has reached the stage of complexity where we must train such men by the thousands to create and build the industrial plant of the future, and we are not making sufficient effort to get them."

Technical bankruptcy is avoidable

"Our engineers and scientists," said Dr. J. J. Grebe, director of the Nuclear & Basic Research Dept., Dow Chemical Co., "have made it possible for our nation to increase its material conversion by a factor of two every 25 years, but on the effort of converting human resources we have had no similar increase in efficiency; some say even a decline." R. T. Sheen, immediate past-president of ISA, warned that the measurement and control field is in for a technical slowdown unless industry can:

(1) educate the current labor force
(2) increase the influx of technical personnel into industry
(3) increase worker efficiency through regional instrumentation centers
(4) enhance worker effectiveness through broader communications on techniques and equipment

He urged:

- technical institutes for training
- engineering extension services in the land-grant colleges (will this mean county instrumentation agents?)
- more effective military training
- enhancement of the programs in the National Science Foundation and in the Foundation for Instrumentation, Education & Research
- development at the National Bureau of Standards of a national center for information on control

On behalf of ISA he proposed a task force to study the four basic needs and to apply his or similar recommendations.

Thomas R. Jones, president of Daystrom, Inc., added these recommendations:

- government encouragement of cross-fertilization of military development and industrial adaptations
- locally-based education similar to the engineering, science, and management training programs conducted early in World War II

Neither Sheen nor Jones surveyed the customer training programs conducted by manufacturers in the measurement and control field, nor the 8,000 technicians which these programs improve as human resources every year (CtE, Dec. '56, page 55). However, it is conceivable that the programs would benefit from benign legislation proposed by Grebe, Easton, and Sheen. Grebe proposed tax deductions for private and corporate spending for education, pointing out that the same net cost would, in this way, double or triple educational funds. Easton recommended support of Bill S4160, intended to provide federal aid for adult education. And Sheen, speaking as president of Milton Roy Co., proposed a credit against taxable income of $1.50 for every $1 contributed to education.

Bureaucracy gets in the way

Jones recommended easing of the many economic, legal, and personnel burdens of the still economically immature control industry by:

- breaking up bureaucratic delays, expensive reports, and legal fees that block the road when small businesses, so prevalent in the control industry, wish to combine for corporate security.
- effecting broader participation, by the small companies, in government R&D instrumentation programs

Sheen added a proposal to permit a business to depreciate, or expense, its first $50,000 of "bricks-mortar-tools" investment in any one year by whatever method it choses.

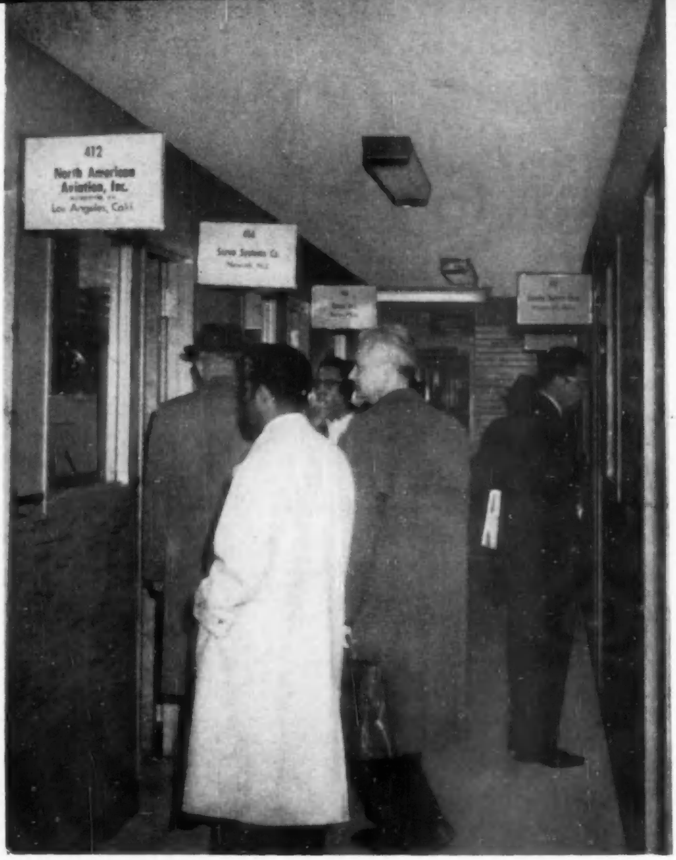
Labor marks time

Robert C. Siciliano, Assistant Secretary of Labor, projected that as planning and training periods are successfully completed in small sections of plants, "a new and significantly larger growth in the rate of introducing automation may yet be ahead of us". Extrapolations of the Bureau of Labor Statistics indicate that by 1975 "professional personnel may account for one out of every eight works, one third above the proportion today".

W. E. V.

WHAT'S NEW

Automation Show Puts Products and Particulars into an Intimate Display



Behind the glass in the placard-lined corridor in the picture on the right were the product displays in a new type of trade show. If you like what you saw—you went in. But once inside there was no escape: your briefing was thorough, your indoctrination rigorous. (If you were not a competitor, that is.) Morning clinics held by the exhibitors in similar rooms offered even less diluted commercial schooling. General concensus of attendees: we went through the mill but it was good for us.

Meetings- and shows-conscious engineers faced a full week in New York last November. Three affairs drew them to the big city. The annual meeting of the ASME started on Monday, the 25th, at the Statler Hotel and continued through to Friday with a complete program of technical meetings. Downtown, at the New York Trade Show Building, the Third International Automation Exposition opened on Monday, too, with five floors of exhibits, engineering-employment recruiting offices, and classrooms for clinics. Uptown at the Coliseum, the Power Show claimed attention from control engineers interested in commercial and military atomic power, the IGY satellite, and prime movers.

Notable at the Automation Show were the morning clinics. Here, manufacturers proved, with either a hard or soft sell, how effectively they can instruct in the basic principles and applications of the instruments and equipment they make. The broad, interested, and unrestricted attendance at the sessions gave the clinics the appearance of extension courses in manufacturers' training programs. The 20 sessions, estimated by CtE's Ed Kompass at 200-300 listeners per day, attested to the practicality of this method of dispensing instrumentation know-how.

Ed also reported on one of the sessions held by the Simulation Council at the Automation Conference. "This session was chairmanned by Jack Sherman of Lockheed Missile. After a go-around on the virtues of analog vs. digital computers—which sounded a little one-sided since most of those attending were council members representing analog computer manufacturers—the meeting centered around a paper by Convair's Stan Rogers. This paper, on changes needed in analog computers, was read by John McLeod.

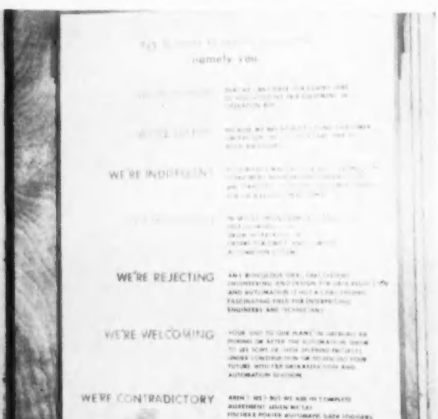
"Rogers based his conclusions on two points undoubtedly influenced by Convair's particular experience:

1) computers continue to grow larger and more expensive;

2) many computers are operated on two shifts per day, these shifts often dealing with quite different problems; this requires removal of one problem from the machine and setup of another.

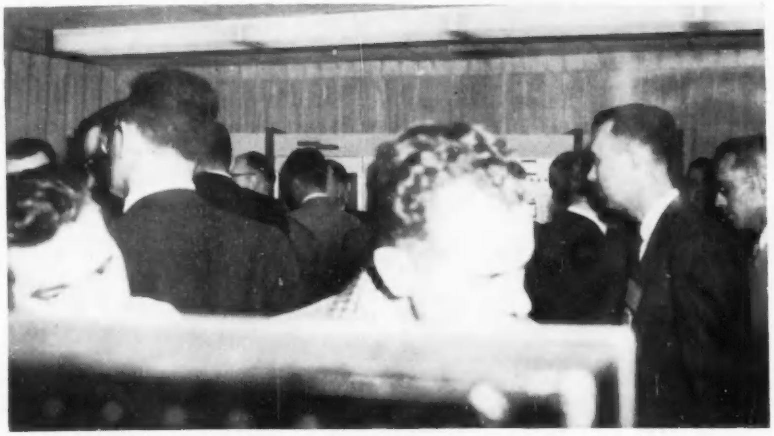
"The conclusions as to what's needed: more compact storage of setup data; more complete storage—including scale-factor pot settings, function generator settings, initial condition settings, etc.; such storage should be parallel for speeding setup time; new patchboard verifier to list connections and print out any changes made since last setup; an automatic marginal checking system such as used on many digital computers to catch failing components before they cause difficulty during a problem run.

"Most of those attending this meeting predicted that digital techniques would be part and parcel of setup and

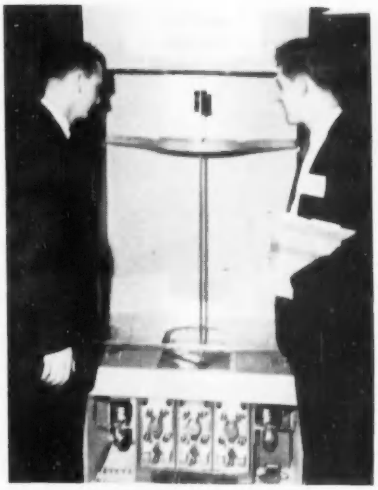


ONE ROOM WAS UNFILLED
Fischer & Porter never did get its equipment and people to the room it rented. Read its sign (on the door in the picture at the right) for the reasons why.

BEHIND THE GLASS
HERE ARE SOME OF THE THINGS THEY SAW . . .



Berkeley's DO/IT computer packed the room.



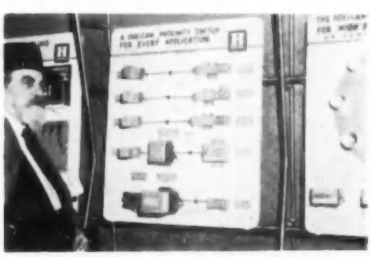
Reeves' "Electronic Juggler" entranced.

Three full floors of the New York Trade Show Building held display-window room exhibits of product. Another similar floor was completely devoted to recruiting rooms. And there was a single old-fashioned open floor exhibit on the second level of the building. As the pictures at the right indicate, the exhibits included a good stress on computing techniques (there were eight computer makers with displays), a strong emphasis on the rapidly developing machine tool control field (three working machine control systems were on view, at least a dozen other firms specializing in this area had exhibits too), and a broad array of new (see Doelcam proximity switch line below) and old hardware for mechanizing production lines. Also included: a fair amount of specialized hardgoods measuring equipment such as interferometers, torque and load transducers, dry product weight pick-ups.

Bendix intrigued with infallible gambling.

People viewed Airborne's "Inchworm".

Farrand's digital control and viewer.



The new Doelcam line got rapt attention.

checking circuits in future analog computers. Goodyear said it expects to show such a version of GEDA in a few months, while Berkeley was already displaying its new EASE 1100 analog computer. The new EASE goes a long way in meeting the needs established during the discussion of Rogers' paper and got a good play from the crowds at the show. On the EASE 1100, pot settings can be made manually or via a typewriter that prepares a punched paper tape. The digital data from the tape are converted to analog by stepping switch voltage dividers, and high gain servos set the pots to match this analog voltage. Setup time savings claimed: 7½ hours (from 8 hours to ½ hour for a typical large problem). The pots can be trimmed manually to correct initial setup errors and optimize coefficient values; then a new tape can be made automatically, and this becomes the master for future setups."

OTHER CONTROL CONCLAVES

ASME-IR Division

ASME's annual meeting included six sessions sponsored by the Instruments & Regulators Div., some of these in conjunction with other divisions. Keeping up their reputation for advanced contributions, the committee and the authors barraged listeners (30-60 per session) at the New York Statler's Keystone room with a wide variety of papers.

Control system stabilization, analysis of nonlinear systems, design of servos, mechanical pressure elements, frequency response representations of temperature measuring elements, and control equipment and computer applications came in for full treatment.

One of the livelier sessions was sponsored by IRD's Dynamic Systems Committee. Here, seven authors gave 5-min rundowns on projects and schemes on which they are working but which have not yet reached the status warranting a full-fledged technical paper. Discussions following presentation of the "Technical Memoranda" attested to the value of this session. The essentially nonmathematical presentation, restricted to one or two major points of interest, allowed the audience to easily follow the speakers' thoughts and to come back during the discussion periods with straightforward comments, advice, and questions. Authors and listeners alike seemed to gain from this unique session.

Rufus Oldenburger, in another session, showed that system stabilization

DOWN THE CORRIDORS of the Automation Show in New York went the job seekers. Some dubbed this part of the show the "labyrinth of opportunity".

INSIDE ONE RECRUITING ROOM Mergenthaler had unusual success with its "atmospheric" display, designed to acquaint visitors with the careers awaiting them.

could be obtained, under certain simple conditions, by injecting a large-amplitude high-frequency signal into the system. In two companion papers, Taylor Inst. Cos.' Geraldine Coon and Bob Looney showed: first, that the temperature-measuring elements in most processes can be represented by a single order lag for those cases where the element does not contribute appreciable (less than 30-deg) phase lag of the total allowable 180-deg lag in the open loop; second, that this approximating time constant can be determined from the properties of the fluid being measured as well as from the parameters of the measuring system. These latter papers are abstracted starting on page 191. *H.R.K.*

Eastern Joint Computer Conference

The Eastern Joint Computer Conference convened in New York City Dec. 10 for a two-day session on "New Developments in Computers". From the papers presented the trends appear to be toward: high speed—typically, IBM's STRETCH, which will use 10-megapulse circuitry, and RemRand UNIVAC's LARC, which utilizes multi-level switching; more solid-state devices—transistors, ferrite cores, ferractors, are sharing the spotlight to the exclusion of vacuum tubes in most new designs; large-capacity short-access-time memories — Lincoln Lab's 5-megapulse TX-O transistor computer, for example, uses a fast-access magnetic core memory of 65,536 19-bit words; random access memories — ElectroData's DATAFILE is the newest, with a capacity equal to about five magnetic tape machines and an average access time of around 12 sec.

One computer, Bell Labs' LEPRECHAUN, which uses over 5,000 transistors, is designed with extreme flexibility in its logical interconnections for research in programming and logical design of digital computers for real-time control.

Because of our primary interest in control applications of the computer, we can't resist quoting England's "father of radar", Sir Robert Watson-Watt, who quipped at a press lunch-

Electronic Associates set up its analog computer in the digital camp, and Epsco exhibited the analog-to-digital link.

con, "'Giant brains' are fine—provided they are properly matched to eyes, ears, noses, and so on. . . ." Sir Robert exhorted the assembled computer engineers to develop an "accepted glossary of terms into which the specification of the potential computer users' problems can be dissected". This could then become the language of communication between the users with their varied problems, and the manufacturers who understand their machines' capabilities —much as mathematics is a universal language to mathematicians anywhere in the world. *E.J.K.*

2nd IRE Instrumentation Conference

"Atlanta's Biltmore Hotel was the scene of the second IRE Instrumentation Conference on Dec. 5-7," reports Georgia Tech's Mario Goglia. "Some 800 people attended, of which 250 were paid registrants. This registration was much lower than last year and was attributed to too broad a coverage of material with consequent lowering of the level of papers and to the fact that the conference started in midweek.

"The Atlanta section of IRE sponsors this affair as a regional activity of the Professional Group on Instrumentation. Based on the experience of this meeting the planners are going to restrict the topics next year, raise the level of the papers to be presented, and thus try to attract national attention.

"The salient papers at this session were on solid-state devices. Probably the keynote paper of the conference was McMahon's discussion of the transistorized core memory. Parish's paper on phase-angle analogs in out-of-sight control instrumentation was a close second in caliber.

"The exhibits held in conjunction with the technical sessions were excellent. About 100 companies displayed computing equipment, telephone circuit devices, precision instrumentation, and closed-circuit television with ingenious adaptations."

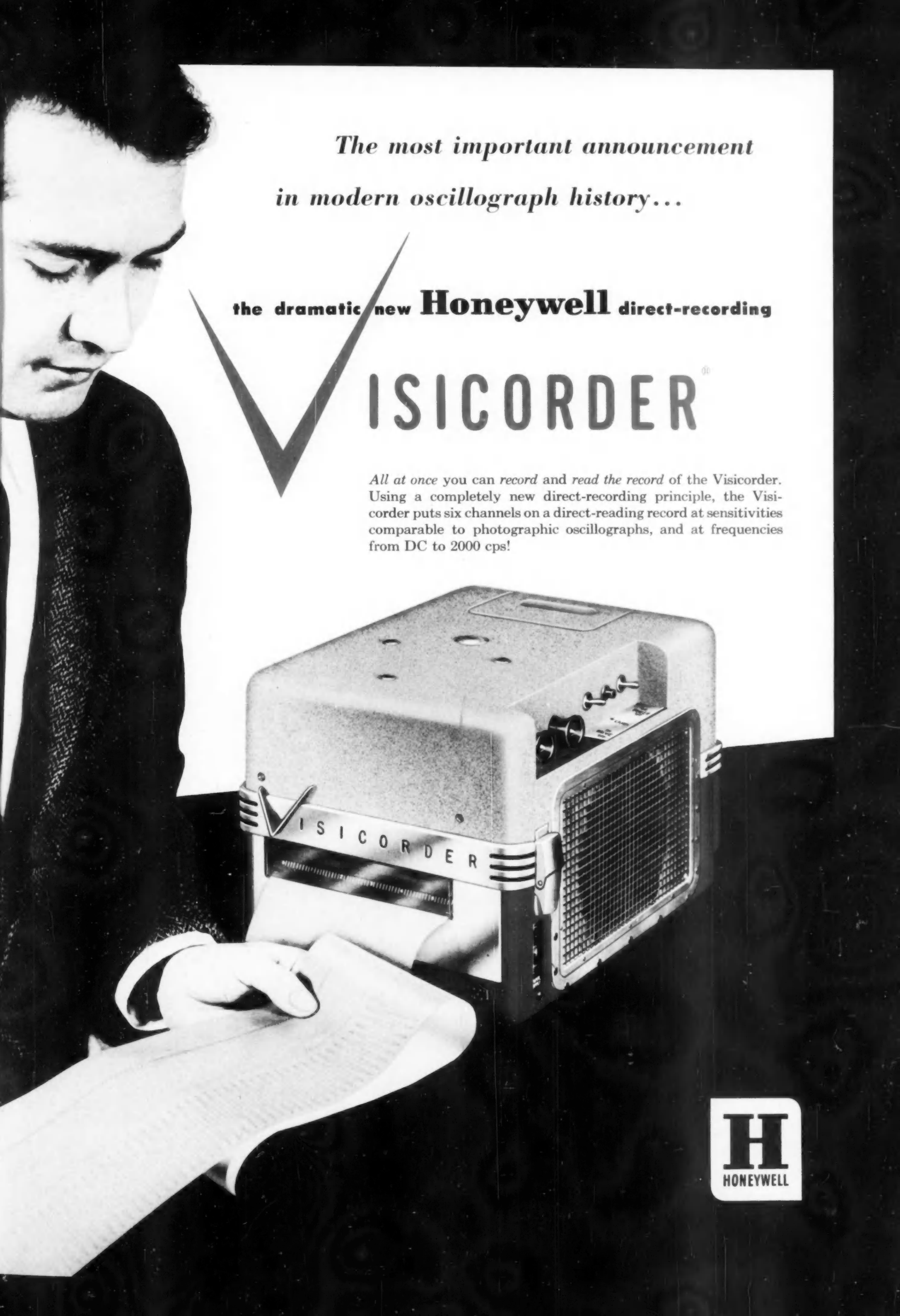
ISA Foundation Elects Two Officers, Plans for Future

Moving along at a dignified pace, the ISA's new Foundation for Instrumentation, Education & Research has planned an early-in-the-year (Feb. 24) meeting in St. Petersburg, Fla., to start rolling on many of its important projects. Formal organization of the foundation is already whipping into shape: Rex Bristol of The Foxboro Co. is temporary chairman of the board of trustees and R. Croft of J. H. Whitney Co. is secretary-treasurer. Both were elected at a get-together in New York last December of the foundation's trustees, consisting of the following: A. O. Beckman, president of Beckman Instruments, Inc.; R. J. Jeffries, assistant to the president of Daystrom, Inc.; C. D. Jolliffe, first vice-president of RCA; T. R. Jones, president of Daystrom; W. Kushnick, executive director of ISA; Robert Sheen, Milton Roy Co.; J. T. Vollbrecht, president of ISA and president of Energy Control Corp.; and Bristol and Whitney.

ISRAELI COMPUTER with high-speed memory

Research programs at the Weizmann Institute in Israel will be solved faster with the new high-speed memory installed in the institute's giant computer. The memory, supplied by Telemeter Magnetics, Inc., of West Los Angeles, was shipped to Nehovoth, Israel, last spring. The computer was assembled under the direction of Dr. Gerald Estrin, formerly of the Princeton Institute of Advanced Study. With the new memory, the Israeli computer operates with a day shift only; formerly, three shifts worked around the clock.

The only high-speed digital electronic computer in the Midle East, the Weizmann Institute's 'giant brain'


The most important announcement
in modern oscillograph history...
the dramatic new Honeywell direct-recording
VISICORDER
All at once you can record and read the record of the Visicorder. Using a completely new direct-recording principle, the Visicorder puts six channels on a direct-reading record at sensitivities comparable to photographic oscillographs, and at frequencies from DC to 2000 cps!
VISICORDER
H
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THE **NEW** *VISICORDER,* perfected after years of research by the Heiland Division of Honeywell, combines the high frequency and high sensitivity characteristics of photographic oscillographs with the convenience of a direct-recording instrument.

By means of a completely new type of recording paper, light source, and optical system, the Visicorder makes use of mirror-type galvanometers to record phenomena from DC through 2000 cps *without* peaked amplifiers or other external compensation.

The record requires no liquids, vapors, powder magazines, or other processing materials. Development is accomplished by external light only as the record emerges from the oscillograph.

The Visicorder records are stable and require no further processing under normal conditions. They may be subjected to room light for extended periods without fading, and are permanent indefinitely when protected from light. Should it be necessary to subject the records to direct sunlight, they may be chemically "fixed" (in room light) using conventional photographic practices.

Visicorder records are reproducible by several methods using commercially available equipment.

Since the Visicorder operates on light-beam galvanometers, traces may deflect the full 6″ width of the chart, peak to peak, and their deflection is not limited by adjacent channels.

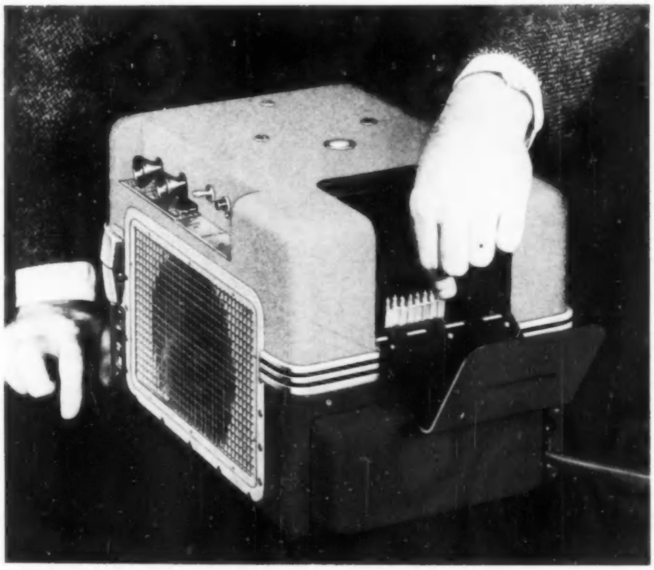
The remarkable exclusive features of the Visicorder make it the ideal recording oscillograph for applications where readable, permanent analog records are required and for additional uses where the measured phenomena need to be monitored or where immediate recorded results are desirable.

GENERAL FEATURES

FREQUENCIES	From DC to 2000 cps without peaked amplifiers or other compensation of any kind.
SENSITIVITIES	Comparable to photographic-type oscillographs.
RECORDING METHODS	Records directly on paper which requires no powder magazines, liquids, vapors, or other processing. Records are immediately visible and usable. Daylight loading. Accommodates recording paper 100 feet in length. Indicator shows unused recording paper available.
NO. OF CHANNELS	6 channels on 6″ wide paper plus provisions for two timing traces.
DEFLECTION	Full 6″ peak to peak. Traces may overlap; not limited by adjacent channels.
RECORD SPEEDS	0.2, 1, 5, and 25 inches per second, minute, or hour.
GALVANOMETERS	D'Arsonval-movement mirror galvanometers with choice of natural frequencies to suit individual requirements.
AMPLIFICATION	None required for most applications.
POWER	115 volt 60 cycle AC operation. 4 amperes.
DIMENSIONS	10″ height; 15″ depth; 10″ width.
WEIGHT	37 pounds, complete and ready to operate.
PRICE	$2,500.00, less galvanometers. Galvanometers $150.00 each.

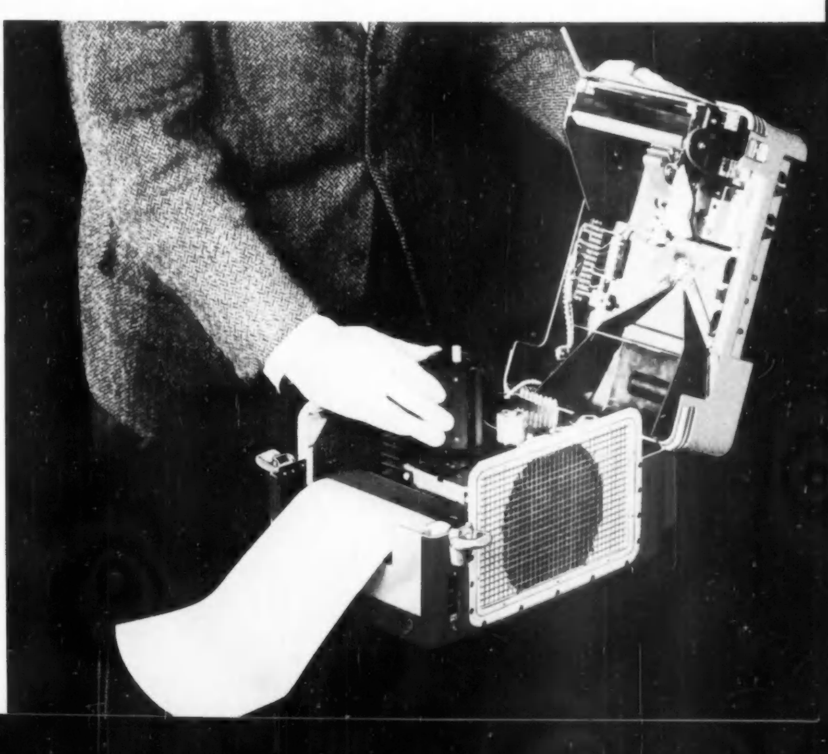
Deliveries starting January, 1957

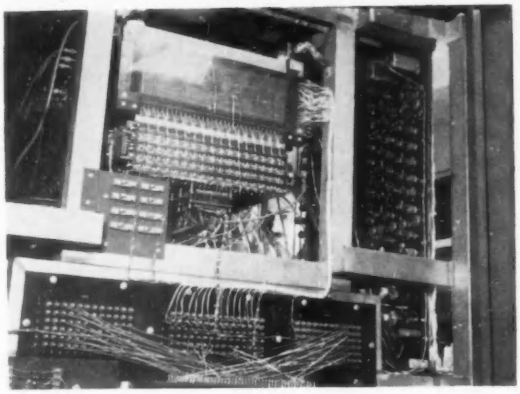
➊ *THE VISICORDER* is the first and only photographic-type oscillograph that can be loaded with recording paper in daylight. The paper speeds can be selected while the instrument is in operation. The light spots from the galvanometers are *visible from the exterior* at their point of contact with the paper; thus phenomena can be monitored simultaneously with their recording.



➋ *GALVANOMETER ADJUSTMENTS* may be made through a panel-covered opening in the back of the instrument. Other operating controls —power on-off, lamp switch, paper drive and paper speed—are located on one convenient panel. Galvanometers are of the familiar Heiland solid-frame type: high sensitivity, accurate balance, high stability, low drift, in a versatile range of frequencies and sensitivities.

➌ *SERVICE* on the Visicorder is extremely easy, since the instrument opens completely as shown. All components—galvanometers, recording lamp, transmission—are completely accessible.





Part of Telemeter Magnetics high-speed memory is shown installed in the Weizmann Institute's digital computer. This view shows one of forty similar ferrite matrices. Each matrix can hold 4,096 binary digits.

will be used for many purposes, among which will be geophysical surveys and meteorological work. In general, the computer will further "the development of agriculture, industry, and social progress of Israel, in order to advance science for the service of mankind".

All Around the Business Loop

▶ For the most part, **McGraw-Hill's Dept. of Economics** observes in its December report on the nation's business outlook, control makers and those on the periphery of the control field had a good year in 1956 and can expect a better one in 1957. For example:

"The machine tool industry had the best peacetime year in its history. Shipments this year will run about $875 million, one-third more than in 1955. Backlogs on the books of machine tool builders still represent seven months of activity at peak production rates. Shipments in 1957 should run at least 10 percent above the figure of 1956. The McGraw-Hill new orders index of metal-working machinery points to a better year ahead: new orders have been running about 20 percent above a year ago. . . .

"Output of the instruments and controls industry is up about 15 percent in 1956 [but, interpolate CtE editors, capital investment in new tools and plants by these same companies will be down 8 percent in 1957]. New orders ran one-third more this year than a year ago, so the outlook for this industry is also very bright. It is expected that shipments of instruments and controls in the year ahead will run about 25 percent above 1956 [and, say the editors, 44 percent above 1955]. . . .

"This year the manufacturers of electrical apparatus are having the best year in their history. Output is up 15 percent over a year ago [and, it is said, will rise 27 percent above 1955 in the year just beginning]. New business has been coming in faster than shipments going out, so backlogs have continued to build up. Companies in this field have enough back orders to turn out heavy electrical equipment at an increasing rate through 1957—and still have a big year's output left over for 1958. Production of electrical apparatus may run as much as 10 percent higher next year."

▶ Six years ago the **Recorder-Controller Section** of **Scientific Apparatus Makers Association** went out after a number of maverick terms used to describe the response of industrial instruments. Last November the roundup was completed: the mavericks trotted in docilely and were worked up into Tentative Standard RC3-12-1955, which will hold them until next December, when they will be considered for adoption as a permanent SAMA decree. The December 1957 date, though barely a year off, will actually terminate two years of deliberation on the new standard: it became effective at the end of 1955 but was kept under wraps while editorial changes were being made.

Briefly, SAMA has zeroed in on three terms—accuracy, error, and sensitivity—which, say the drafters, have been "used with a variety of meanings and frequently the exact meaning is open to question". The result of the association's work has been to nail down:

- the difference between accuracy, error, and limit of error
- the effect of scale units, scale span
- accuracy rating expressed in scale units, percentage scale
- test conditions for determining accuracy ratings
- definition of sensitivity, deadband, response time
- test conditions for evaluating response time

The several definitions that start off

WHAT'S NEW

the standard indicate its objective. "Accuracy of an Instrument", for example, is defined as that number or quantity which pinpoints its limit of error. Other general definitions: "Error of an Instrument", the difference between the indication and the true value of the quantity being measured; "Limit of Error of an Instrument", the maximum error throughout the scale under specified conditions; "Accuracy Rating of an Instrument", the limit which errors will not exceed when the instrument is used under specified operating conditions".

Also defined are: "Scale Units", the units of a measured variable shown on the scale, such as degrees F, psi, etc.; "Scale Span", the algebraic difference between the top scale value and the bottom scale value expressed in scale units; and "Scale Length", the distance traveled by the indicating pointer or pen from one end of the scale to the other. There may be two distinct values for indicator-recorders, one for the indicating scale and one for the recording scale.

More specific definitions cover accuracy rating, test conditions for determining SAMA accuracy rating, dead-band, ultimate sensitivity, unit sensitivity, response time, response time for substantially exponential response, and test conditions for determining SAMA response time. Under "Calibration Equipment" in the section on test conditions for determining accuracy rating, SAMA has this to say: "Calibration equipment with a known accuracy at least ten times that of the instrument under test is desirable."

Copies of Tentative Standard RC3-12-1955 can be obtained by writing to the Recorder-Controller Section of Scientific Apparatus Makers Association, 522 Fifth Ave., New York 36, N. Y.

▶ The First National Bank of Boston, the oldest in the country and the largest in New England, handles 200,000 checks a day, or 55 million every year. On a typical day it also takes care of 19,000 deposits and a large volume of stock transfer work. It is, to put it mildly, a very busy bank indeed. Just recently word was received that a new employee was coming to work for First National, an employee that can read and write at the rate of 60,000 digits per second, can handle simultaneously 1,000 multiplications, 4,000 additions, or 5,000 comparisons, and values itself at $1.75 million.

Its name is Datamatic 1000, and its

installation at First National will be only its second since its development (the first is to be at Michigan Hospital Service). A product of **Minneapolis-Honeywell** and **Raytheon Mfg. Corp.**, which together own **Datamatic Corp.**, the data-processing and computing system will go to work in Boston on one of the largest bookkeeping operations in the U. S. Proof: it will take ten magnetic tapes, each capable of storing 37,200,000 digits of information, to make up the daily master file for the bank's 700,000 stock records in its Stock Transfer Section. Despite its size however, posting for this particular job is expected to take Datamatic less than an hour a day.

A bear for work, First National's machine will rush into still other breaches when it has finished reading and sorting checks (to be printed in magnetic ink), working on consumer and business loans, and grappling with stock transfer operations. Awaiting it will be such things as personal trust accounting, payroll and expense distribution, and any other types of transactions which the bank may go into as it continues to grow.

► A major bottleneck confronting even the newest computers has to do with output speed. One solution (Datamatic's, above) will be to read and sort according to magnetic printing. But there are others in the works, too, and among these is xerographic printing, which will be a joint development of **Stromberg-Carlson Div. of General Dynamics Corp.**, **Haloid Co.**, and **Horizons, Inc.** The plan is to combine S-C's Charactron shaped-beam cathode-ray tube, a component of the SAGE system, with xerography, a fast, dry, electrostatic printing process pioneered by Haloid. Horizons' role in the project will be principally research, and it will be sponsored in this activity by Haloid.

► Another joint venture–this one looking toward establishment of two independent sources for a very precise subminiature rate gyroscope–has been launched by **Sanders Associates, Inc.**, of Nashua, N. H., and **The United States Time Corp.** of Waterbury, Conn. Before the agreement, Sanders made the missile and instrumentation component exclusively, then sold it to U. S. Time for resale. Now Time, with new research laboratories at Irvington-on-the-Hudson, N. Y., plans to develop the gyro and related instruments on its own and market them all under its own label.

► A new laboratory and engineering

Splitting Split Seconds

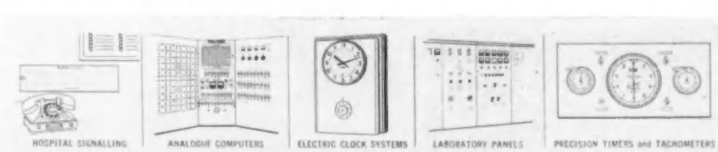
FOR ACCURATE MEASUREMENT OF ELAPSED TIME... AS CLOSE AS 0.001 OF A SECOND

THE STANDARD PRECISION TIMER

is the indispensable STOP watch in laboratory and test cell, on experimental nuclear projects, precision production, check and final inspection. Many important applications in almost every industrial plant and research laboratory.

Built in many different advanced designs — both panel mounted and portable case — to meet almost every conceivable need for the precise measurement of time. Synchronous motor drive. Electric clutch controlled by manual switch, automatic switch or output of electronic tubes. Manual or electric zero reset.

Model	Scale Divisions	Totalizes	Accuracy
S-100	1/5 sec.	6000 sec.	±.1 sec.
S-60	1/5 sec.	60 min.	±.1 sec.
SM-60	1/100 min.	60 min.	±.002 min.
S-10	1/10 sec.	1000 sec.	±.02 sec.
S-6	1/1000 min.	10 min.	±.0002 min.
S-1	1/100 sec.	60 sec.	±.01 sec.
MST	1/1000 sec.	.360 sec.	±.001 sec.
MST-500	1/1000 sec.	30 sec.	±.002 sec.



HOSPITAL SIGNALLING · ANALOGUE COMPUTERS · ELECTRIC CLOCK SYSTEMS · LABORATORY PANELS · PRECISION TIMERS and TACHOMETERS

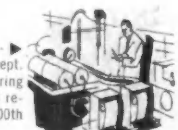
THE WORLD'S MOST ACCURATE and RUGGED time measuring instrument...

THE STANDARD PRECISION TIMER

◀ Timing photo-cell controlled exposures in automatic photo printing machine at Eastman Kodak Co.

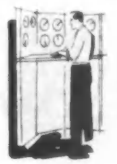
▲ Timing test action in automatic transmission research at one of world's largest automotive manufacturers.

For Glenn L. Martin's ▶ Gunnery Trainer — in 12-channel Playback System designed by Cook Research Laboratories.

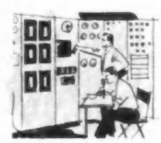


At Bendix — Westinghouse Research Dept. laboratories — measuring brake application and release time to 1/100th second. ▶

▲ At General Electric Co. — Trumbull Division — measuring operating time of circuit breakers.



◀ At American Brass Co. — indicating metallurgical analysis in Direct Reading Spectroscope by Baird Associates.



At Yucca Pass, Nevada ▲ Proving Grounds — helping maintain split-second control of atomic bomb tests.

▲ Timing elements required to complete telephone connections in Bell Telephone offices across the United States.

Send Today for Bulletin No. 198

THE STANDARD ELECTRIC TIME COMPANY
Springfield 2, Massachusetts

THE STANDARD ELECTRIC TIME Co.
105 Logan St., Springfield 2, Mass.

Please send Bulletin 198.

Name.................... *Title*..............

Firm....................................

Address..................................

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WHAT'S NEW

building near the University of Michigan will be the home of **Bendix Aviation's** recently organized **Bendix Systems Div.**, "an outgrowth," reported Bendix's President Malcolm P. Ferguson, "of the new engineering concept called the systems approach". General manager of the new arm, which will concentrate on weapons systems requirements of the Dept. of Defense, is Russell D. O'Neal, formerly director of the **Systems Planning Group.** He'll have about 1,000 men—engineers, scientists, and supporting personnel—under him within three to five years, Ferguson said.

► Shortly after its formation by **Kieley & Mueller, Inc.,** of Middletown, N. Y., K&M's new **Nuclear Power Equipment Div.** was awarded valve contracts totaling $750,000. The valves, intended for nuclear-powered propulsion, will have their own control systems. The division building them is being staffed by personnel from both the automatic control and nuclear fields.

► A new **Raytheon** electronics laboratory under Manager Homer C. Knauss will concentrate on such airborne military items as Doppler navigation instruments, aircraft intercept radars, altimeters, and surface radars. Most of the personnel for the Maynard, Mass., facility comes from the company's **Aircraft Systems Dept.;** Knauss himself was formerly airborne systems manager in the **Radar Dept.** of the **Wayland Laboratory.** The new lab will be part of the company's **Government Equipment Div.**

► **Daystrom, Inc.,** has filed an application with the AEC for permission to build and operate Argonaut-type nuclear reactors. Apparently, the permission is simply a matter of routine, for Daystrom's **Nuclear Div.** expects to break ground for the development early this year. The DART reactors (Daystrom Argonaut Reactor Training) will be components in integrated training programs for research reactor operators and engineers. Daystrom is the first company to make this kind of bid.

► Two former **Electronics Corp. of America** men, George H. Wayne and George F. George, have formed **Applied Electronics Corp.** of Boston, which is concerned with research, development, and manufacture of devices for analog and digital computation, data handling and conversion, and automation. Wayne, formerly chief engineer of Electronics Corp.'s

(*Continued on page 186*)

Portion of Eclipse-Pioneer's synchro calibration and test facility.

WHY IT PAYS TO SHOP AT THE BENDIX "SUPERMARKET"

— NATION'S LARGEST PRODUCER OF SYNCHROS

SHAFT POSITION-TO-DIGITAL CONVERTERS

Eclipse-Pioneer Coded Commutator type shaft position-to-digital converters are miniature devices for converting Analog information to Binary Digital form. Designed for Digital control systems, data processing equipment, telemetering applications, or computers. Especially suited to air-borne use.

Specifications:

	Model GS-1-A1	Model GS-2-A1
Type output	8 digit gray (Reflected Binary Code)	7 digit Natural Binary Code (double brush)
Shaft resolution	1 part in 256	1 part in 128
Current rating	.015 amps. (max.) per digit with non-inductive loading	.015 amps. (max.) per digit with non-inductive loading
Shaft speed	Max. continuous input of 150 revs. per minute	Max. continuous input of 150 revs. per minute
Input torque	0.2 ounce-inch (max.)	0.4 ounce-inch (max.)
Diameter of unit	15/16 inch	15/16 inch

In buying precision synchros, doesn't it make a lot of sense to insist on getting exactly what you want, when you want it—and at minimum cost?

Best way to be *sure* you get all three is to depend on the Bendix "Supermarket".

Our mass synchro production facilities . . . the nation's largest . . . are constantly turning out just about all types of synchros imaginable. This means we can offer you immediate delivery of most synchro types—and minimum cost on all synchro types, even for small quantity orders.

You can depend on the quality of Bendix synchros, too. They will equal . . . or exceed . . . the accuracy of any other synchros made today. Sound reasons why you'll be ahead to rely on the experience and mass-production facilities of *Bendix*.

District Offices: Burbank, Calif., Dayton, Ohio, Seattle, Wash.
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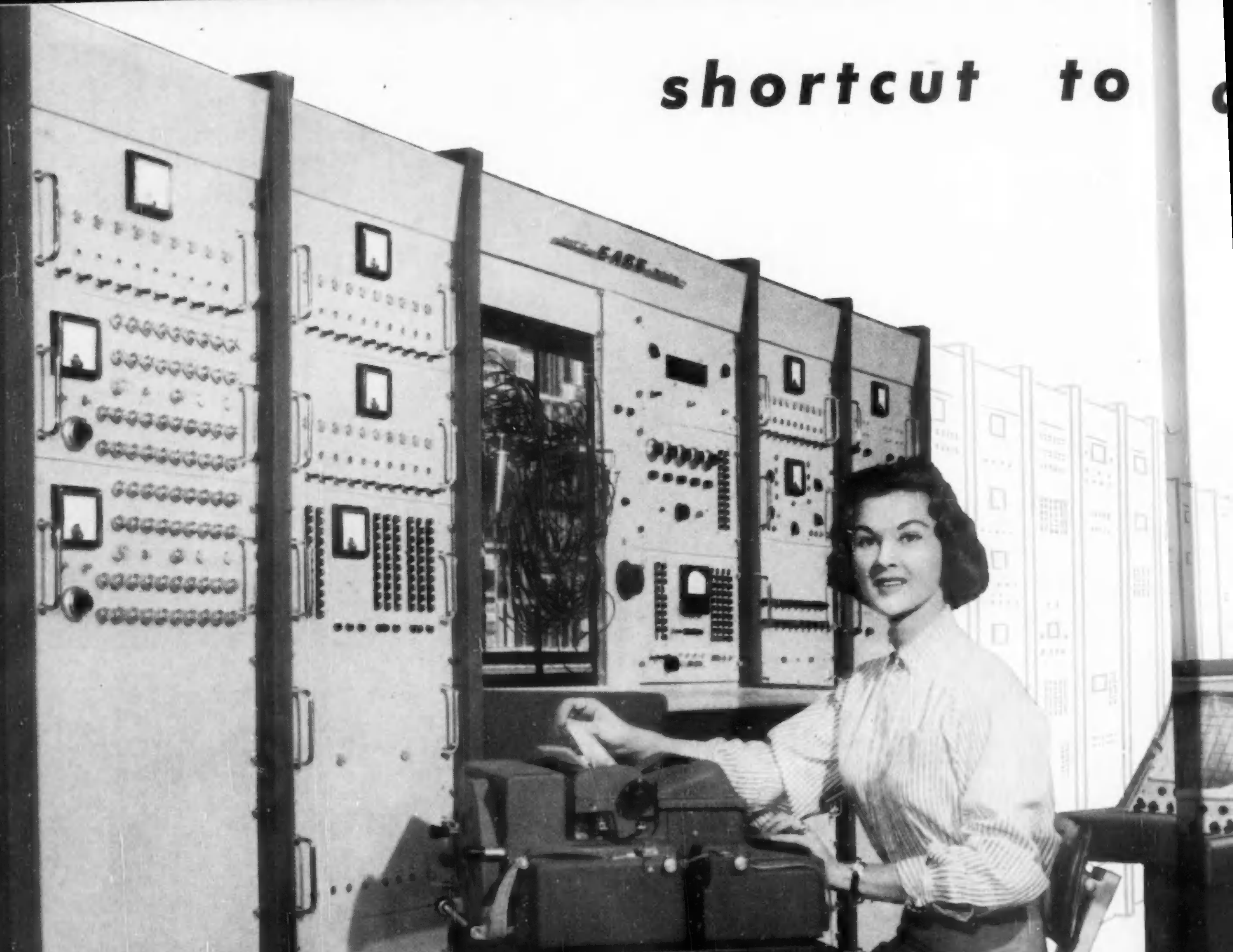
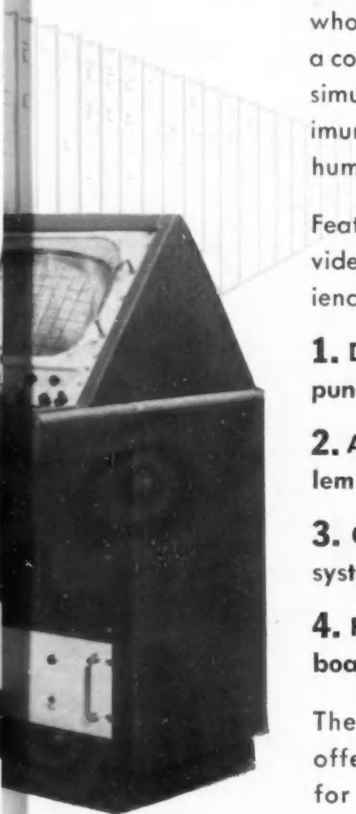
shortcut to



DO/IT (Digital Output-Input Translator system) is a major feature of the new EASE* 1132 for automatic operation and high accuracy.

accomplishment

DO/IT WITH EASE*



Berkeley's new EASE* 1132 represents a wholly-new concept in analog computation — a complete **system** for solving computation and simulation problems **automatically**, with a minimum of human attention and possibility for human error.

Features of the EASE* 1132 that provide improved operational convenience, speed and accuracy include:

1. Digital input-output by means of punched tape or electric typewriter.

2. Automatic static or dynamic problem checking.

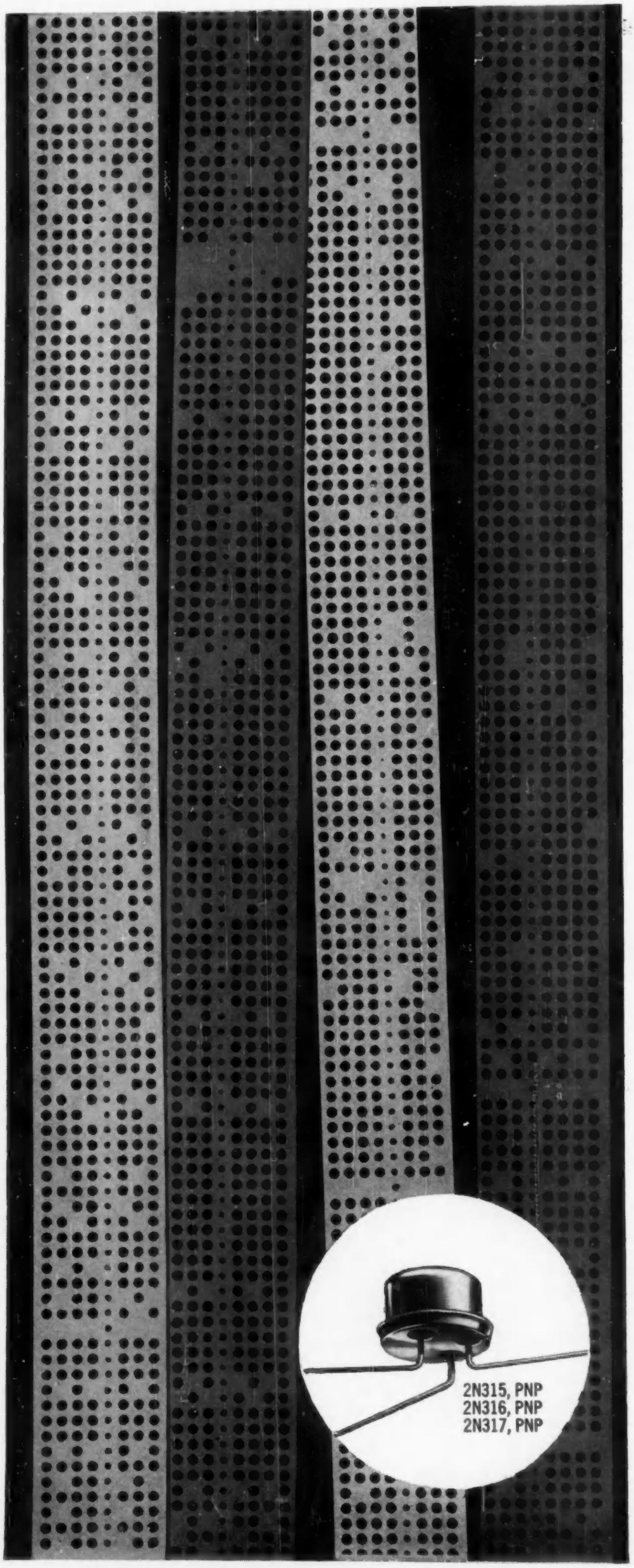
3. Complete pushbutton monitoring system.

4. Fully shielded, color-coded patch board.

The advanced-design EASE* 1132 offers today's greatest opportunity for better utilization of scientific-engineering brainpower, faster research and development progress. Why not investigate **now?** A letter will bring details promptly; please address Dept. L2.

Beckman®/ **Berkeley** *Division*
Richmond 3, California
a division of Beckman Instruments, Inc.

*Trademark



General NEW HI-SPEED SWITCHING TRANSISTORS Assures Computer Reliability

Computer engineers long seeking PNP transistors in applications requiring high current and fast switching will specify General Transistor's new 2N315, 2N316, and 2N317 for peak reliability.

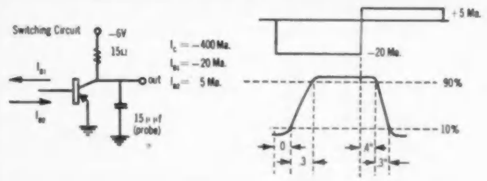
2N317: As developed by General, a typical switching speed of .3 of a microsecond at 400 milliamps of collector current is possible with only 20 ma. of drive current.

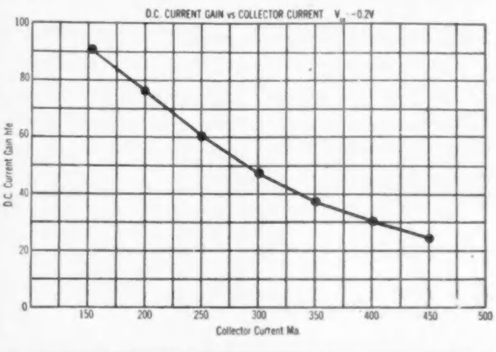
The series resistance of these GT transistors, when conducting, is ½ ohm; the nonconducting series resistance is as high as 10 megohms with a result that approaches optimum efficiency at high current levels.

Computer manufacturers know they can depend on General's engineering and development as well as their quality and service. That's why GT is the largest supplier of transistors for computers.

CHARACTERISTICS

Parameter	Conditions	Min	Typical	Max
Collector-Base Voltage (Vcbo)	Ic = –25μa, Emitter Open	–20V	–30V	
Collector Cut-off Current (Icbo)	Vcb = –5V		–1μa	–2μa
D.C. Current Gain (hfe)	Ic = –400ma, Vce = –.2V	20	30	50
Alpha Cut-off Frequency (fafb)	Vcb = –5V, Ic = –1ma		20mc	





Write for GT's special Computer Transistors Specifications Bulletin.

GENERAL TRANSISTOR CORP.
Richmond Hill 18, N. Y.—Virginia 9-8900
Cable: Transistor New York

Know your timer types...

Grouping the multiplicity of timer types into four broad classes simplifies equipment designer's job:

INTERVAL TIMERS

The first—and simplest—group is that of the interval timers. These consist basically of a motor, an arm or cam, and a switch. To operate the timer, the user simply sets the mechanism manually to the desired time interval. This action transfers switch contacts that start the timer motor.

The motor drives the timer mechanism to the end of the timing cycle. At this point the switch returns to its original position and the motor shuts off.

A variety of dials, knobs, push-button start, automatic reset features, special housings and additional load switches may be used, but the basic operation is the same. Interval timers are used in applications that require frequent changes in setting—like photographic exposure timing.

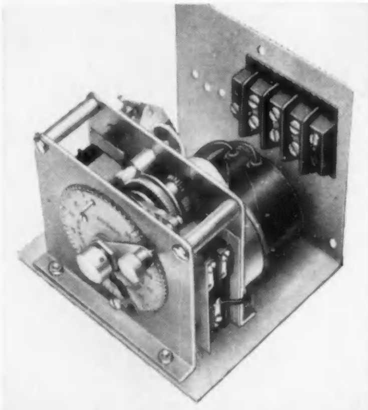
INTERVAL TIMER of advanced design, the new Cramer Type 241 features large easy-to-read dial, pushbutton start, automatic and immediate reset and repeat accuracy of ± ¼ of 1% of full scale. Bulletin PB-241.

TIME DELAY RELAYS

The time delay relay represents the second large group of timing devices. These units provide accurately timed delays between the closing of an external remote switch and the transfer of a load switch. At the end of each cycle, the motor shuts off automatically, and the standard device remains in this "timed out" condition until the clutch is released allowing the timer to reset. Other variations reset automatically at the end of a cycle. Models are available to either reset on power failure or suspend operation until the circuit is restored.

Special housings, additional switches, various clutching mechanisms, and a wide selection of wiring arrangements make the time delay relay an extremely versatile device.

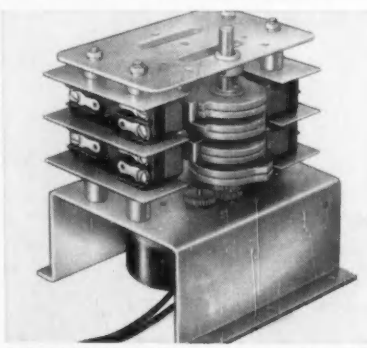
A typical application is for regulating processes such as heat treating where the timer controls the amount of time required to produce the desired change in the metal.



TIME DELAY RELAYS—like the Cramer Type 440A above—are rugged, dependable and accurate devices to control from 1 to 5 load circuits. For flush, surface or panel mounting. Bulletins PB-310 and PB-311.

CYCLING TIMERS

In the third category are found the cycling timers. Fundamentally these units are made up of the driving motor, a cam (or arm) which is revolved continually by the motor, and a switch operated by the cam. The cycling timer produces switch transfer repeatedly, according to the cam cuts, as long as the motor runs.



CYCLING TIMERS—like this Cramer Type 520 come in 1 to 8 poles. Normally factory preset for highest accuracy. Operating speeds 1 rev./6 sec. to 1 rev./day. Bulletin PB-510A.

Variations of the cycle timer include changing the motor speed, cutting cams in an almost infinite number of combinations, and adding switches. The cam setting may be fixed or adjustable. Special housings are available. Cycle timers are used to control a program or sequence of events as in a signaling system.

TIME TOTALIZERS

Time totalizers, or elapsed time indicators, range in complexity from a simple motor-driven counter to the precision time totalizer used in scientific research. The former, usually used as a running time meter, counts discrete time *units* from tenths of a second to hours. The more elaborate time totalizer is actually an electrical stop clock capable of measuring time intervals to an accuracy of ± 0.01 second. Running time meters are used to record the operating or down time of industrial machines. They are offered in many models—with or without reset, in portable or die-cast enclosures, etc. Time totalizers are commonly applied in test equipment for industrial and military laboratories.

TIME TOTALIZER of laboratory quality. The Cramer Type 690 features easy-to-read scale and pointers for fast, exact readings, accuracy to ± 0.01 second. Reset lever conveniently located on dial face. Bulletin PB-610.

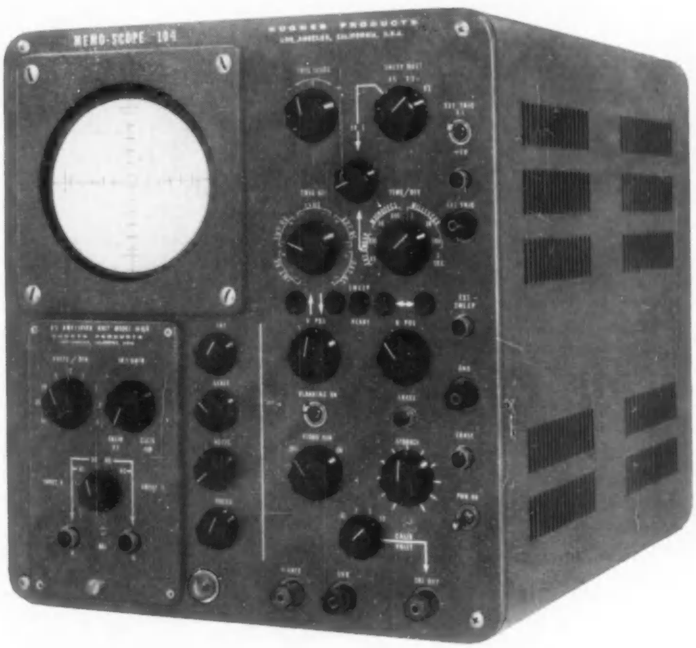
LEARN MORE about these four basic timer types from Cramer's complete line. Just ask us to send you our bulletins on the types that interest you. Nearly 100 varieties are *stocked* for immediate shipment. Cramer Controls Corporation, Box 46, Centerbrook, Connecticut. (Formerly R.W. Cramer Co.) 7.1

TALK IT OVER WITH

CRAMER CONTROLS
CORPORATION

ANNOUNCING THE 104 MEMO-SCOPE

The MEMO-SCOPE Model 104 is a new memory oscilloscope with a selection of 5 plug-in preamplifiers that will satisfy the most critical production, test and laboratory requirements. MEMO-SCOPE incorporates the famous Hughes-developed Memotron direct-display storage tube that captures and retains any number of traces indefinitely at a constant intensity until intentionally erased. Traces are readily visible in a brightly-lighted room, and may be easily photographed for file records.



MEMO-SCOPE 104 SPECIFICATIONS

ERASURE: internal waveform generator triggered by front panel push button or by external switch.

DC BLANKING: CRT grid direct coupled to external or internal blanking gate allows beam to be turned off except during sweep and insures constant sweep-time intensity over any sweep duration.

DEFLECTION PLATES: available at rear terminal strip for direct connection.

MAIN VERTICAL DEFLECTION AMPLIFIER: frequency response of DC to 700 kilocycles within 3db. Rise Time of $1/2$ microsecond.

TRIGGERED LINEAR SWEEP: range of 10 μsec to 10 seconds per division, adjustable continuously or in 18 calibrated steps. Trigger: vertical amplifier signal, AC line or external pulse, either polarity, DC or AC coupled. Minimum external trigger amplitude: 0.1 volt. Neon ready lamp indicates sweep is at left side of screen, ready for trigger.

AMPLITUDE CALIBRATOR: available at front panel terminal—one kilocycle square wave with peak-to-peak amplitude of 0.01, 0.1, 1.0 or 10 volts, within 3%.

BEAM POSITION INDICATORS are four neon lamps showing position of writing beam when not on screen.

ILLUMINATED GRATICULE: scale calibrated in $1/3$" squares in 10 × 10 array.

RACK MOUNTING: Model 104 available on standard 14" × 19" relay rack panel.

DIMENSIONS: 13" wide, 14" high, 20" deep. Etched circuit epon-glass electrical chassis. Hinged camera mount optional.

OPTIONAL PLUG-IN PREAMPLIFIERS INCREASE FLEXIBILITY

(All units with frequency response from DC to 250 kilocycles down 3db.)

WB/4. Wide Band, DC.

WB/SE/5. Wide Band, DC plus Speed Enhancement.

HS/6. High Sensitivity—1mv/division differential.

HS/SE/7. High Writing Speed, High Sensitivity.

HS/D1/10. High Sensitivity, Dual Input.

For additional information or demonstration of the new Model 104
write to HUGHES PRODUCTS
MEMO-SCOPE
International Airport Station
Los Angeles 45, California

HUGHES PRODUCTS

Progress Report:

SCHRADER AIR PRODUCTS CAN MAKE PRECISION OPERATIONS EFFICIENT

• Let's clear the air about close tolerances

We've faced it. Lots of manufacturers still think air is as unpredictable as the weather report. But others know better, because they've taken the time to let a little sunlight on the subject. These open-minded ones are utilizing Schrader Air Products, not just to hold work or blow away chips, but to produce complex units to close tolerances.

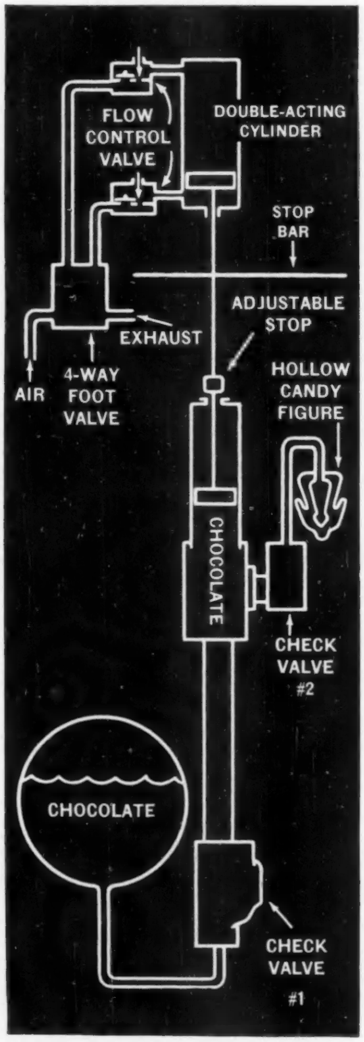
Air is a big boy now. It has grown up fast because automation came because pennies needed pinching. Because many operations in manufacturing turned out to be just plain dangerous. Then engineers found air was not only efficient, economical, and safe, but that products were already designed and produced to make air a logical way of performing hundreds of special jobs.

FOR EXAMPLE:

• Sweet words about air from a candy maker

At a Buffalo, New York, candy company, Schrader Air Products have been used to perform a complex measuring operation. To within one gram! Six Schrader double-acting cylinders are used to fill a bank of six more single-acting cylinders with a prescribed amount of chocolate. When a foot valve is released, the chocolate is forced into wax figurines, exactly filling them. And the entire installation is even covered and kept at a constant temperature to insure the proper chocolate viscosity.

Take a look at the schematic. It shows the arrangement by which the Schrader Air Products are adapted to an operation which might at first seem far outside the limits of air use. It was possible because some engineers put on their thinking caps.



Schematic shows how Schrader Air Products are adapted for precision handling of liquid chocolate.

• Talk about air's advantages being automatic—lend an ear

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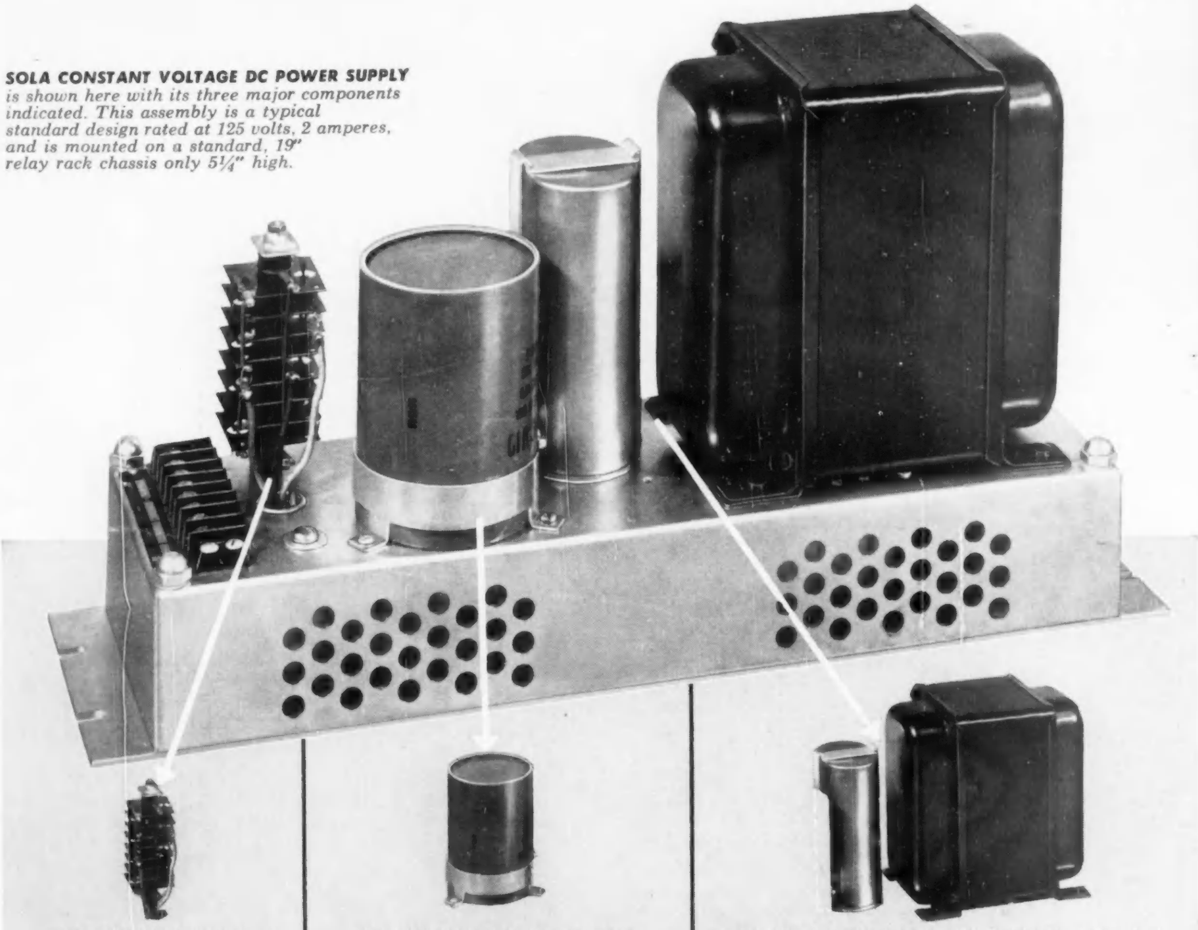

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SUPERSONIC LOCKHEED X-7, shown with Marquardt powerplant installed, was recently revealed as a stratospheric test-bed for powerful new engines under test for U.S.A.F. missiles. The needlenose X-7, which is launched from a B-29, is parachute recovered after each flight so that it may be flown again. Rheem power amplifiers form a part of the electronic control system of the X-7.

A NORTHROP SNARK, intercontinental guided missile, roars from its launching cradle at a U.S.A.F. base to begin a long range test flight over the Atlantic ocean. The Snark, which couples inter-continental range with the ability to carry a first priority warhead, utilizes Rheem amplifiers for a share of the telemetering chores.

LOCKHEED'S F-104, prototype Starfighter, climbs on razor blade wings to the upper stratosphere at ground speed equaling its speed in straight and level flight. The ship is described by Hall L. Hibbard, Engineering Vice President of Lockheed, as "a masterpiece of simplification." Rheem light weight, small space, amplifier components play an important role in this simplification.

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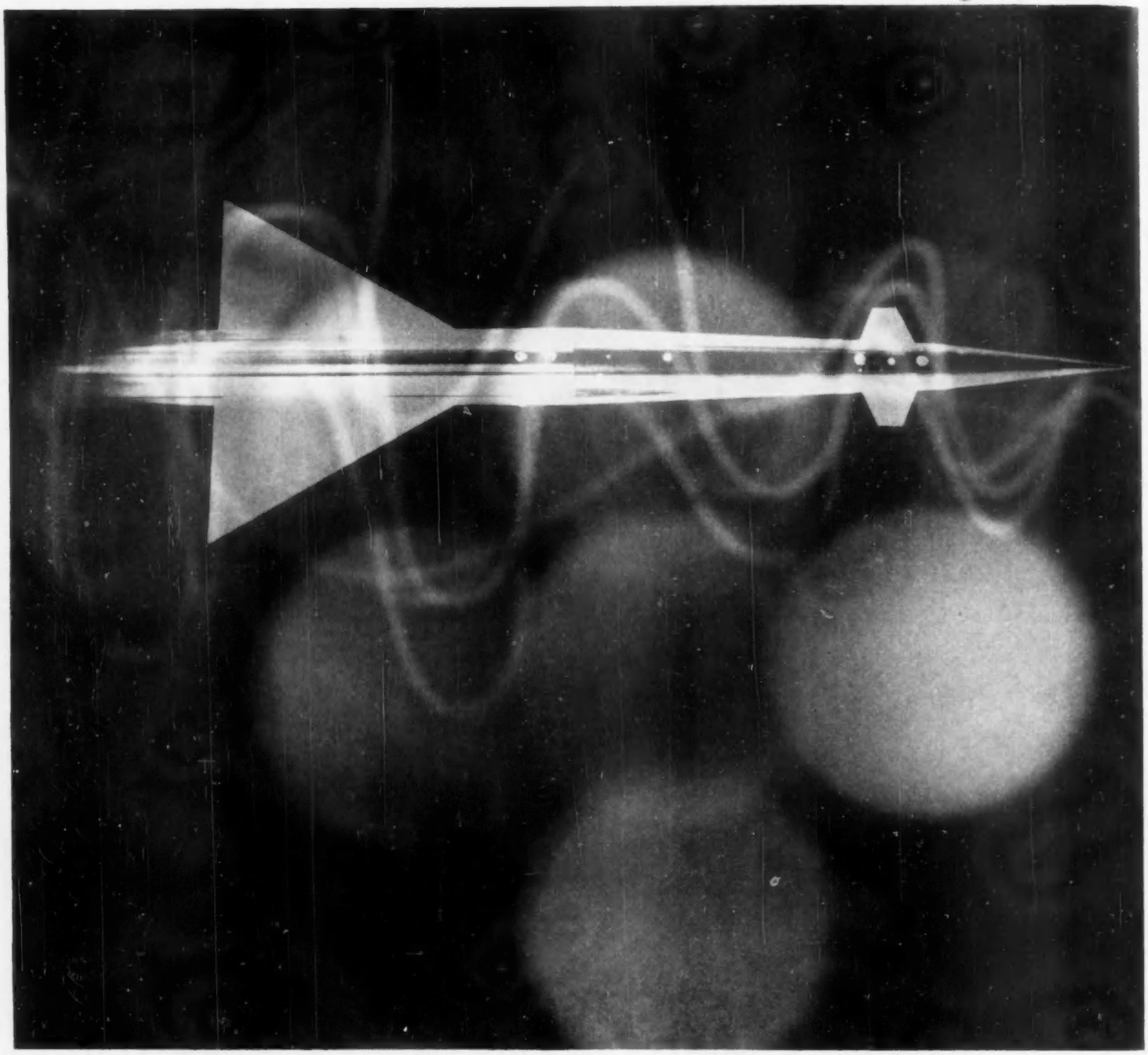

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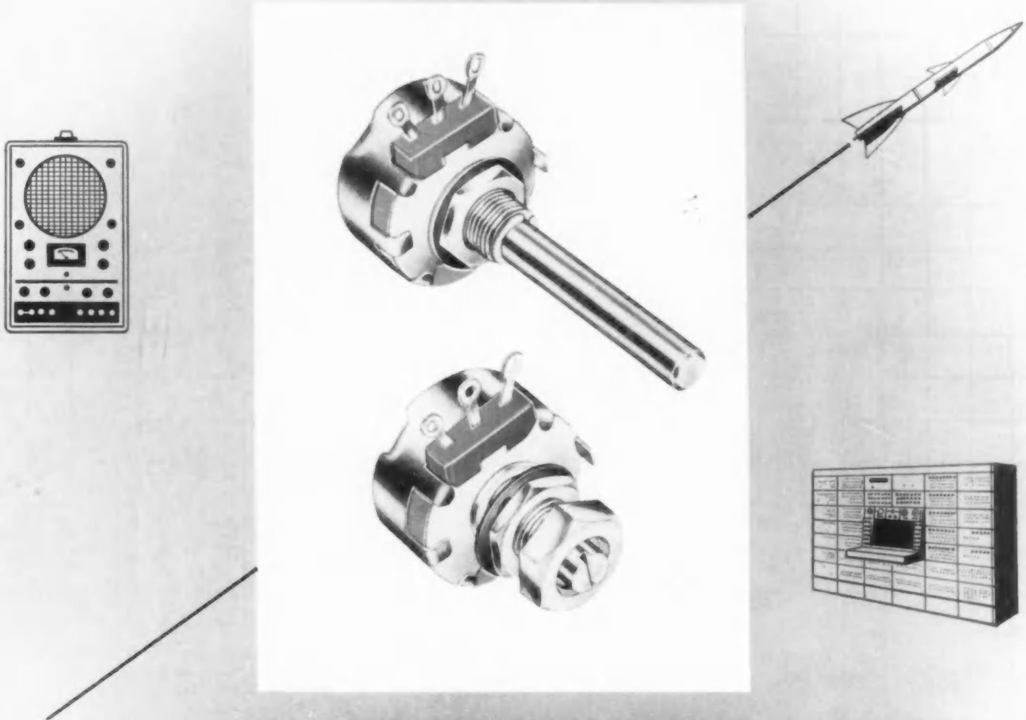

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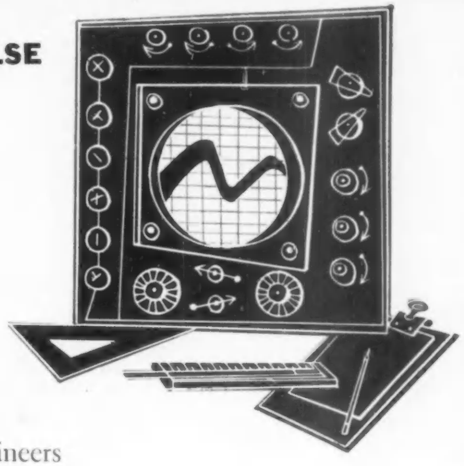

What, Where & Why Control Engineers Migrate

While the best way to fill your roster of control engineers may be through training, the quickest and most-favored seems to be to lure them from competitors. A recent trade show (page 29), gave over a whole floor to recruiting. Turn to the back of this magazine for still another approach.

Two surveys by CONTROL ENGINEERING and McGraw-Hill's Classified Ad Div. supply information on background and movement of control engineers which should help either A) the company desperately seeking new talent, or B) the company desperately seeking to hold the talent it now has. Our questionnaire—an attempt to draw a profile of the "composite" control engineer—went to 3,400 subscribers and drew 1,219 returns. The results below concern his background.

College degrees held (%):	BSEE	BSME	BS	MA-MS	PhD	Others
	45	22	21	23	3	12

Years practicing in field (%):	OVER 15	11-15	6-10	2-5	LESS
	25	16	33	22	3

Migration and new ideas

Next the survey tried to find out how often this composite engineer moved around in the field and where he went to. First, how long has he been where he is now?

Years with present employer (%):	OVER 15	11-15	6-10	2-5	LESS
	16	8	17	36	23

Did the man do control work in his previous job? What kind? We separated these questions into two basic categories—military and industrial. The answers are tabled below:

TYPE OF WORK INVOLVED IN:	MILITARY	INDUSTRIAL	BOTH
1. Work now doing (%)	35	36	29
2. Previous work (%)	48	48	51
3. Past vs. present (%)		(now doing)	
A) military in past	61	14	30
B) industrial in past	21	64	26
C) both in past	18	22	43

The table above suggests a constant flow of control engineers between military-type and industrial jobs. An assay of the effect of this movement is offered by answers to the next few questions. Do those now in military now see future industrial applitions in their work? 76.5% said yes. Have any new control concepts, initially developed for military, opened the door for new techniques in industry? Of those now in industry, 97.5% said yes. Where in industry might these new techniques

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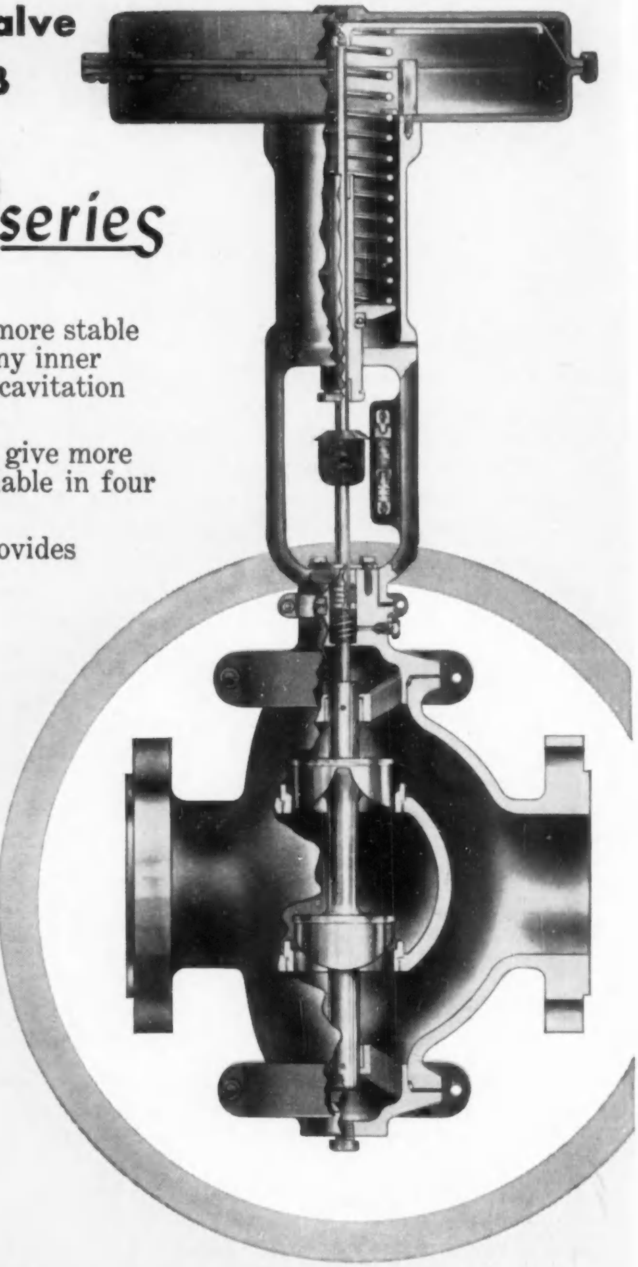

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developed in military apply? Among those now doing both types of work: 56% saw possibilities in controlling processes; 64%, machine tool control; 34% production line control.

Why do these men change their jobs? The other survey, tabulating answers from 2,596 histories on file in the Personnel Departments of 57 companies, offers a revealing picture.

MOST MENTIONED REASONS FOR GOING TO NEW JOBS	MARITAL STATUS Single	1-child	2-child	AGE GROUP <25	25–29	20–24	35–44	>45
1. Starting salary	1	1	1	2	1	1	2	5
2. Potential company growth	3	2	1	3	2	3	1	2
3. Company prestige, reputation	2	3	3	1	3	2	3	1
4. Challenging opportunity	4	4	4	4	4	4	4	3
5. Geographic location	7	5	5	5	7	6	5	6
6. Regular salary increases	6	5	6	A	5	5	6	8
7. Progressive R&D program	5	5	7	6	6	7	7	6
8. Permanent position	10	6	8	8	8	8	8	4
9. Paid vacations and holidays	A	7	9	9	9	9	9	B
10. Company facilities, laboratories, etc.	8	8	10	10	10	10	10	8

A—Educational facilities in vicinity
B—Self-direction, or little supervision

There appear to be three basic motivations in job selection: 1) opportunity within the company; 2) salary and security, 3) prestige and reputation. The table also shows how age and family subtly influence attitude (i.e., the unmarried youngster wants opportunities for study and training; the "oldster" wants security and freedom from unnecessary supervision).

What does all this movement by control engineers mean? To the needy company it means talent can be lured through high salaries and vital work—and that it will not be green. To the control engineer it means a constant upgrading of skill and income—but little roots and less seniority. But its greatest meaning is to the field itself. Answers to one part of the magazine survey indicated that through this restless movement the control engineer has learned to be an objective specialist. He uses electrical (75%), mechanical (68%), optical (16%), electronic (76%), hydraulic (34%) and pneumatic (25%) techniques in solving problems; 60% of the respondents work with three or more of these media. This versatility makes the control engineer the most valuable single force in his field.

"The Chemicals" Find a Springboard

Fifty weeks after chemical process control entered the new era of dynamic analysis — at the American Chemical Society conference in Princeton right after Christmas, 1955 — the American Institute of Chemical Engineers held a round-table discussion on the subject. The weeks-old Process Control Subcommittee of the Equipment Div. conducted the round-table during the Dec. 9-12, 1956 AIChE meeting in Boston. By reviewing the experience of process control engineers, it discovered a growing accumulation of process dynamic analysis procedures — a springboard from which "the chemicals" can launch their designs of future plants.

Out of the discussion came these steps of control systems engineering:

- ▶ high-spotting dynamic analysis to size vessels and to select necessary control actions
- ▶ evaluating alternate control schemes to eliminate impossible ones
- ▶ comparing cost with performance to optimize alternate systems of processes and control equipment

The goal, better process performance at lower operating cost even if the capital costs of the measurement and control equipment run higher, shows a comprehension of systems ideas by chemical engineers.

Speakers pointed to the wealth of techniques for analyzing the dynamics of basic pressure, flow, and liquid level processes. The pointing finger landed on the literature of the acoustic science and turned to the equations which represent the transient propagation of sound in pipes and tanks. But there is nothing to borrow from other fields when it comes to examining transients in distillation, absorption, and separation. This knowledge must come from within the chemical field itself. Happily, it is starting to develop — over two dozen papers on limited aspects of the dynamics of such processing units have appeared in the last three years.

From this springboard "the chemicals" can rise to their needs if they publish their experiences, include control engineering in chemical engineering curricula, and cooperate with other professional groups concerned with control. The AIChE group is already participating in ASME programs. We urge it to follow suit with AIEE, IRE, and the proposed international federation for control systems engineering.

THE EDITORS

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Its high sampling speeds and long life make the mercury jet switch a natural for many difficult commutating jobs. It has less obvious applications, too, however, and several are outlined in this article. Mechanical and electrical characteristics of the switch are reviewed for the reader's convenience.

WILLIAM R. DAVIS
Detroit Controls Corp.

FIG. 1. Multipole mercury jet switches can be made by stacking units to effect a common shaft.

Exploiting the Mercury Jet Switch

The mercury jet switch is a commutating switch that utilizes a stream or jet of liquid mercury as a wiper arm. This technique allows high sampling or cyclic speed for long time intervals, and keeps wear negligible. Because there is no spring constant or resilience in the mercury stream, the switch has none of the "contact bounce" phenomenon found in conventional commutators at high speeds. High speeds also limit the life of conventional commutators.

Mechanical Design. Basically, the Deltaswitch, Detroit Control Corp.'s mercury jet switch, is designed around a simple centrifugal pump, primed by scoops which lift mercury from a sump or pool into a rotating reservoir. The mercury is ejected by centrifugal force from the reservoir through a rotating nozzle as a very fine solid stream or jet, and is directed in sequence against stationary contacts arranged around the rotating nozzle. The sequential contacting occurs in the course of the normal turning of the rotor, which serves both as a pump element and as a portion of the conducting path for the pole contact of the switch. Figure 1 is a sectioned isometric drawing of the switch. In its present form the Deltaswitch has only a dynamic mode of operation; in other words, when the rotor is stationary, no stream exists and there can be no contact between the pole and the various stator pins. The lower limit of operation is about 600 rpm.

The present model has been built with as few as 32 and as many as 128 positions per revolution. As many as 200 could be accommodated with minor modification of the stator assembly. Nozzles with different exit orifice sizes make dwell time particularly flexible. Dwell times from 20 percent to 80 percent break-before-make are possible; so is operation with make-before-break.

As many as 13 standard switches have been stacked with no need for additional supports or structure. The stacking method permits relative phasing of poles to be adjusted while the switch is running. Phase relationships can be established to less than 10 min of arc, and are then retained indefinitely.

Electrical. The series contact resistance through the switch is of the order of ½ ohm, while insulation resistance between adjacent contacts is of the order of 100 megohms when the switch is operating. The maximum allowable potential difference between adjacent pins is 500 volts. At voltages less than 100

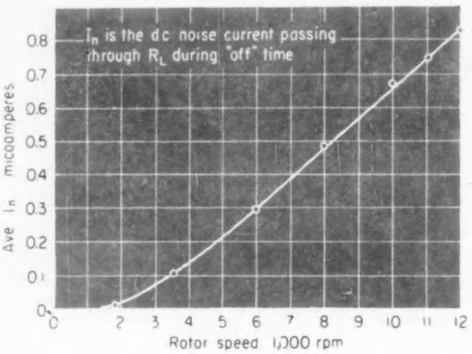

FIG. 2. Break-before-make current noise vs. speed.

volts, currents up to 75 ma can be interrupted without arcing or damaging the contact pins. Over 100 volts, current should be limited to 10 ma.

Life. The switch is inherently long-lived. A standard model, operated continuously for over 6 months (5,000 hours) at 1,800 rpm, thus making over ½ billion revolutions, required only two 30-min maintenance operations for cleaning the mercury.

Noise. Three types of noise have been observed in the Deltaswitch. The first, of least importance in most applications, causes a random duration in the dwell time on a given position from one revolution to the next. This results primarily from uncertainty in the break time of the contact. For example, a contact with a nominal 50-percent dwell may have an actual dwell as high as 55 percent and as low as 45 percent. The distribution of actual dwell time about the nominal dwell time looks like a resonance curve. Although the sharpness of the curve can be controlled to some extent, all the switch parameters which influence this phenomenon are not yet known.

The second type of noise, observed under some circuit conditions, takes the form of short-duration (<10 microsec) random static charge spikes, more or less proportional in magnitude to the resistance across which they are measured. The source is believed to be random-charged mercury particles which strike the contact pins.

The third and possibly most serious type of noise has the appearance of an extraneous direct current proportional to the speed of rotation. While its source is not as yet completely understood, it is believed to be static charge on the mercury stream and contact pins. This is a current-type noise, because the magnitude of the effect is proportional to the resistance of the circuit in which the measurement is made. Figure 2 relates the magnitude of this noise signal to rotor speed.

To date, no voltage-type noise, such as might be attributable to a thermocouple or contact potential effect, has been observed in the switch.

The mercury jet switch is a high-performance commutating switch, and most applications for which it has been considered arise from a need for this type of operation. However, there are other applications.

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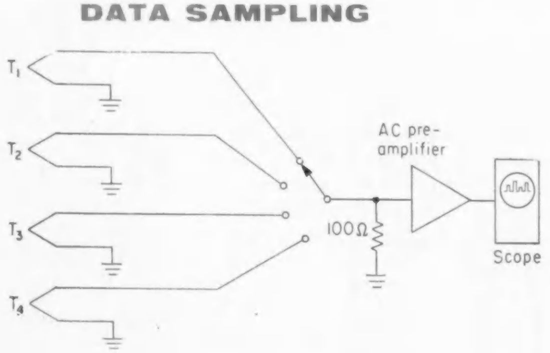
APPLICATIONS

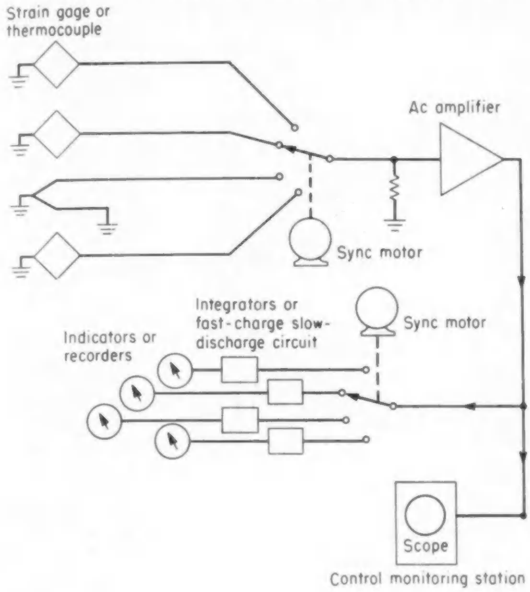
DATA SAMPLING



The most obvious and widespread use of a commutating device is for sampling data. The mercury jet switch, however, by virtue of its low noise level and high speed, considerably extends the scope of items that may be sampled successfully. It has generally been necessary to amplify the signal from each of several low-signal-level transducers in order to sample them. With the mercury jet switch it is possible to sample directly at the primary element and thus eliminate considerable circuit complexity.

Typical of this type of operation is the situation in which it is desired to monitor a large number of thermocouples (or strain gages) and display a temperature "profile" of some process or structure in which a spatial as well as time variation of temperature is anticipated. Because of the low noise level of the switch, thermocouples can be monitored directly to an accuracy of about 1 deg F without preamplifiers of any sort, and subsequently presented on an oscilloscope display at an appropriate central control point. The diagram shows how simple this scheme is. Note that the amplifier following the switch may be the vertical deflection amplifier of the scope and need not be a dc amplifier.

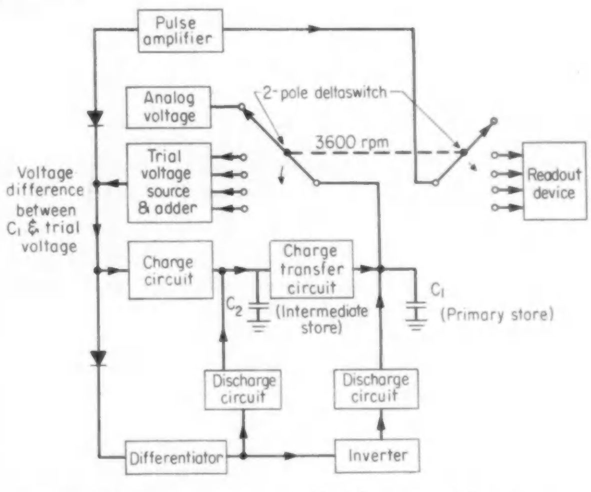
SYNCHRONOUS MONITORING



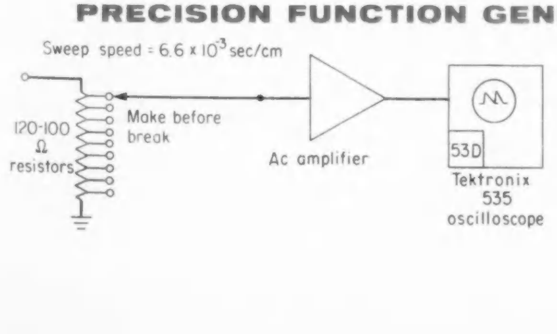
In data telemetering it is frequently necessary to monitor a large number of data points at a location considerably removed from the actual transducer location. In such cases, the scope display mentioned above could certainly be utilized again with the data transmitted on a single pair of wires. It is also often necessary in this type of operation to record some or all of the data points. To do this, a second (decommutator) switch, operating in synchronism with the first (commutating) switch, may be used. Automatic synchronization requires the use of one of the switch channels for the synchronizing information. The short samples of data on each channel resulting from decommutation can be processed by a suitable integrating device or fast-charge slow-discharge circuit, and then recorded on any standard recorder. The system diagram is typical. When decommutating is provided, individual control functions can be associated with each channel after the decommutation, and operation often accomplished in the recorder.

ANALOG-TO-DIGITAL CONVERTER

There are undoubtedly many uses to which a high-speed commutator can be put in the field of specialized instruments. An example is a device for making analog-to-digital conversions. One way of making such conversions is called the trial-voltage method, comparing the analog voltage to be converted with a series of reference voltages in a prearranged sequence. By taking appropriate differences, it is possible to digitize a voltage to an accuracy of one part in 1,024 with 10 trial voltages, each viewed in sequence. Though this scheme is already in use with electronic switches, one of the biggest difficulties lies in generation and preservation of the reference voltages throughout a vacuum-tube system in which tube drift occurs. Circumventing this difficulty with a conventional commutating switch compromises the speed of the system, which is one of the attractive features of a trial-voltage-type converter. With a Delta-switch capable of 10,000 samples per second, it is possible to make 1,000 ten-digit conversions per second. A converter that will make 1,000 conversions per second to an accuracy of 0.1 percent is thus possible. The diagram is a converter now being built that will make 960 4-digit conversions per second.

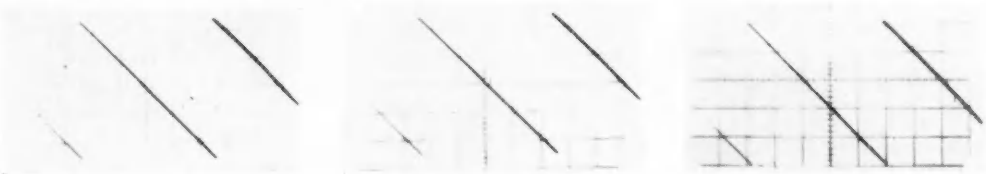


PRECISION FUNCTION GENERATOR

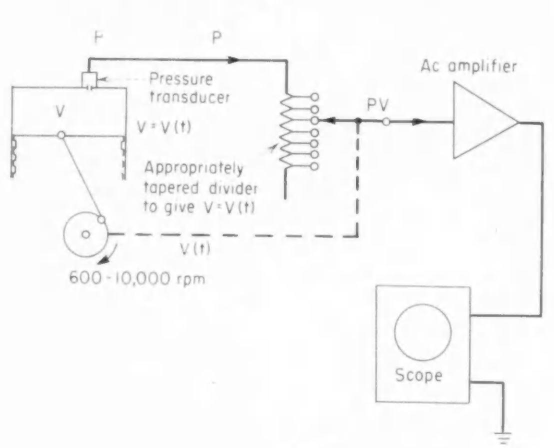


Another use for commutators that can be exploited with a switch capable of operating at high speed is generating repetitive waveforms containing sharp discontinuities. These discontinuities make the waveforms difficult to achieve with vacuum-type circuits. The application is of particular interest if it is desired to synchronize the generation of the function

with a mechanical shaft rotation. The figure shows a linear sawtooth being generated by a make-before-break switch at a rate of 30 cps. It is clear that by appropriate shaping of the resistor-divider being sampled, a variety of waveforms could be generated.



PRECISION ANALOG MULTIPLIER



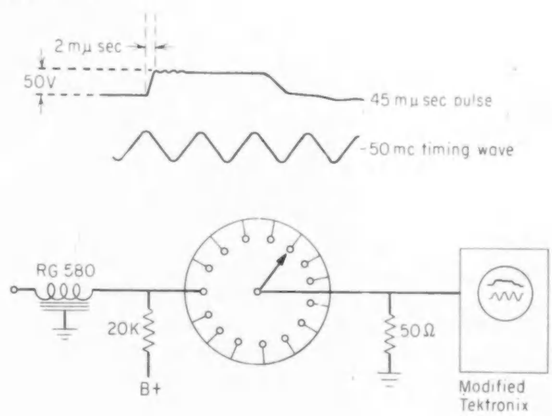
Connected as a multi-tapped precision potentiometer, the switch can also be used as the essential part of a precision multiplier. Suppose it were desired to obtain the product of pressure and volume, either continuously or at specified intervals. The volume might be a known function of position (or time), as in the diagram. By applying a voltage corresponding to either the instantaneous or the sampled pressure to the top of an appropriately tapered resistor-divider, and scanning this divider by a make-before-break switch, the desired product could be obtained at the pole of the switch. This arrangement has possibilities of great accuracy. The accuracy of multiplication would be of the order of one divided by the number of switch positions or scan points on the divider. Hence, in practice, accuracies of about 0.5 to 1 percent could be achieved.

HIGH-POWER-PULSE GENERATOR

In a previous report on the switch[1], mention was made of the fast rise time achieved on the leading edge of the sample, that is, at the instant of contact make. Since this was of interest in certain measurement applications, more detailed investigations of this phenomenon were carried out by Naval Ordnance Laboratory (Corona, Calif.)[2]. This work was undertaken because of the difficulty in the past of getting fast rise pulses at a high repetition rate.

By connecting all the stator pins of a Deltaswitch together in the immediate vicinity of the stator and terminating this common bus with a properly matched transmission line, the switch was found to generate pulses with a rise time of 2 millimicrosec. The figure shows a pulse of 50-volt magnitude being generated across 50 ohms. Thus a peak power of 50 watts was achieved. The duration of the pulse was determined by the pulse-forming network, and was about 45 millimicrosec (normal switch dwell time is about 100 microsec). Since the switch is not required to interrupt the high current being carried, no arcing or deterioration of the contacts occurs.

An important feature of the resulting pulse generator is that it is capable of a very high pulse repetition rate. Previously, rates of the order 100 to 150 per second were considered high for generation



of pulses of this power, and with this rate of rise; with the Deltaswitch, repetition rates of 10,000 are not unrealistic, and even higher values could probably be achieved. Such a pulse generator would be of considerable use in testing the transient response of diodes, in testing switching times in ferrite memories, and in instances where high pulse-repetition-rates allow oscilloscope observation of short-time-duration repetitive phenomena.

Applying Thyratrons to Control

PART II—SERVO APPLICATIONS AND STABILIZATION

Last month author Burnett gave basic thyratron information and procedures for designing thyratron amplifiers as main power supplies for controlling servo motors and for controlling magnetic clutches and motor-generator fields. These design procedures covered selection of motor type and size, and design of the amplifier, error sensing circuit, grid control circuit, and required stabilization.

This month Jim Burnett illustrates five typical thyratron-servo applications, explains stabilization methods used for the various motors and power circuits, and concludes with an original contribution to control technology: development of a nonlinear stabilization method for ideal kinetic-energy damping of thyratron servos.

JAMES H. BURNETT, Electrons, Inc.

TACHOMETER DC VOLTAGE FEEDBACK FOR STABILIZING CONTROL OF A SPLIT-FIELD MOTOR

FIG. 1. Two sets of full-wave connected 1.5-amp thyratrons, operating from a 400-cps source, supply reversing power to a fast-accelerating split-field servo motor rated at 24 vdc. The dc signal voltage, the algebraic sum of dc position error voltage and dc rate voltage (obtained from a tachometer attached to the output shaft), is amplified, fed back to the input, and added to fixed ac bias voltages, which lag each thyratron anode by approximately 90 deg. In this way the error voltage corrects for position error, the rate signal augments stabilization, and the combined signals smoothly vary the firing angles of one set of thyratrons while the other set is held nonconducting. The set that conducts is determined by error polarity and its output power by error magnitude. By using a high ratio of ac anode voltage to dc motor voltage rating, extremely fast motor response can be achieved to correct for sudden error changes.

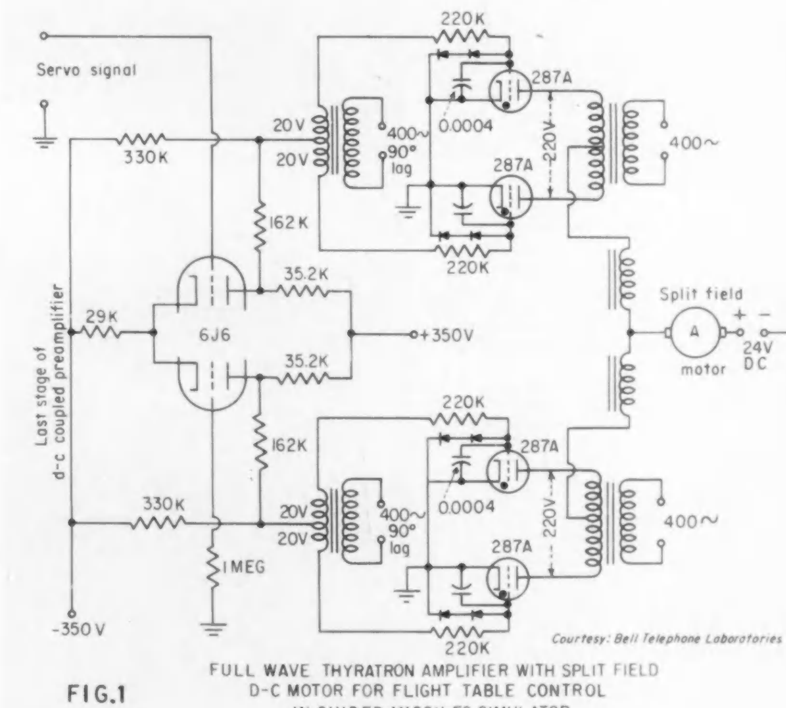


FIG.1

FULL WAVE THYRATRON AMPLIFIER WITH SPLIT FIELD D-C MOTOR FOR FLIGHT TABLE CONTROL IN GUIDED MISSILES SIMULATOR

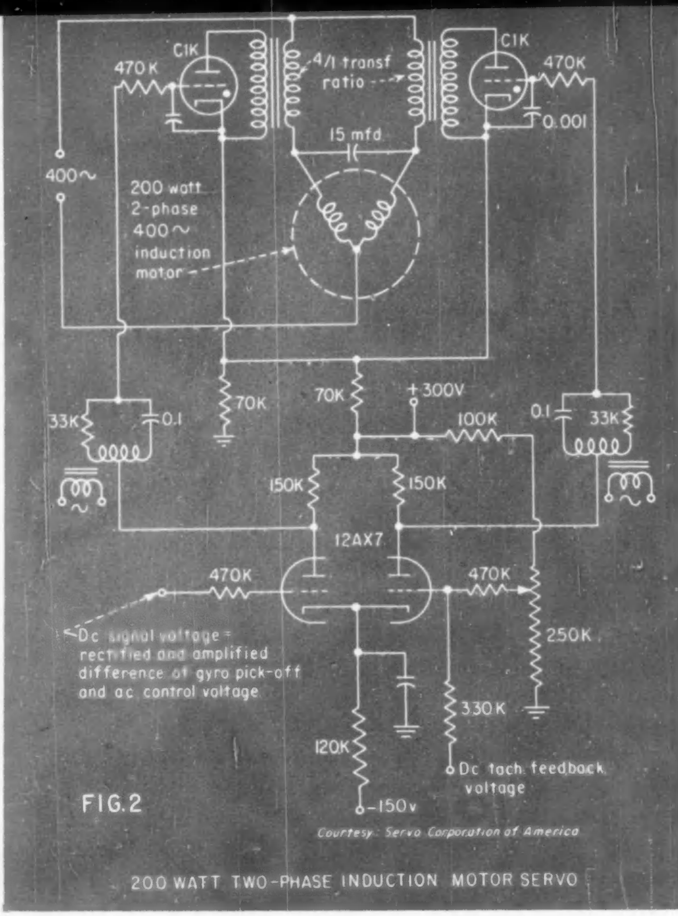


FIG.2

200 WATT TWO-PHASE INDUCTION MOTOR SERVO

TACHOMETER DC VOLTAGE FEEDBACK FOR STABILIZING CONTROL OF A TWO-PHASE INDUCTION MOTOR

FIG. 2. For position servos (and for corresponding velocity servos in the 100-to-200-watt range) employing high-torque, low-inertia, two-phase induction motors, control is obtained by using thyratrons to vary the reactance of transformers in series with the motor windings. In the position system shown the direction of rotation of the 400-cps motor is determined by the thyratron fired. In the corresponding velocity servo the speed of the motor is determined by the firing angle of one thyratron and motor braking is accomplished by firing the other thyratron.

An ac position voltage (from a gyro) and an adjustable ac reference voltage are mixed, rectified, and amplified before the resulting dc error voltage is introduced to one grid of the 12AX7. The dc rate voltage (from a tachometer) is introduced to the other grid and the amplified difference of these two voltages is added to the 7.5-vac biases lagging each thyratron anode voltage by 90 deg. The resulting combined error and error rate signals smoothly vary the firing angle of one thyratron or the other, and hold the opposite tube nonconducting. A 1-amp thyratron is connected directly across each of the high-voltage transformer windings. The transformers have a 4-to-1 step-up ratio to reduce the current ratings of the thyratrons that control the 115-volt motor.

RATE OF CHANGE OF DC ERROR VOLTAGE FOR STABILIZING CONTROL OF A SEPARATELY-EXCITED DC MOTOR

FIG. 3. Here a pair of 6.4-amp thyratrons controls the direction and rotation speed of a 1½-hp separately-excited dc motor. For low-speed positioning servo operation the thyratrons are connected in inverse parallel. For speeds higher than 5 rpm, systems operation switches automatically to that of a full-wave thyratron velocity servo. Low-speed operation: the servo amplifier contains a phase detector, a dc amplifier, a phase-inverter stage, and a lead-lag network (not shown), and the two thyratrons operating half-wave. The error signal obtained from a synchro is phase-detected and passed through the lead-lag network which differentiates the error signal. The resulting dc error-rate voltage is added to a 90-deg ac lagging bias to proportionately control the grid firing angles of the two thyratrons. High-speed operation: the unit acts as a constant speed system, its speed determined by an adjustable dc reference voltage. The circuit is a closed loop in which a portion of the armature back emf (proportional to shaft velocity) developed in the antenna drive motor regulates the input. This voltage is compared with an adjustable dc reference voltage proportional to desired speed, and the difference is amplified and passed through a cathode-follower stage. The output of this stage is added to the fixed ac bias voltages lagging the anode voltage 90 deg to yield a proportional grid control.

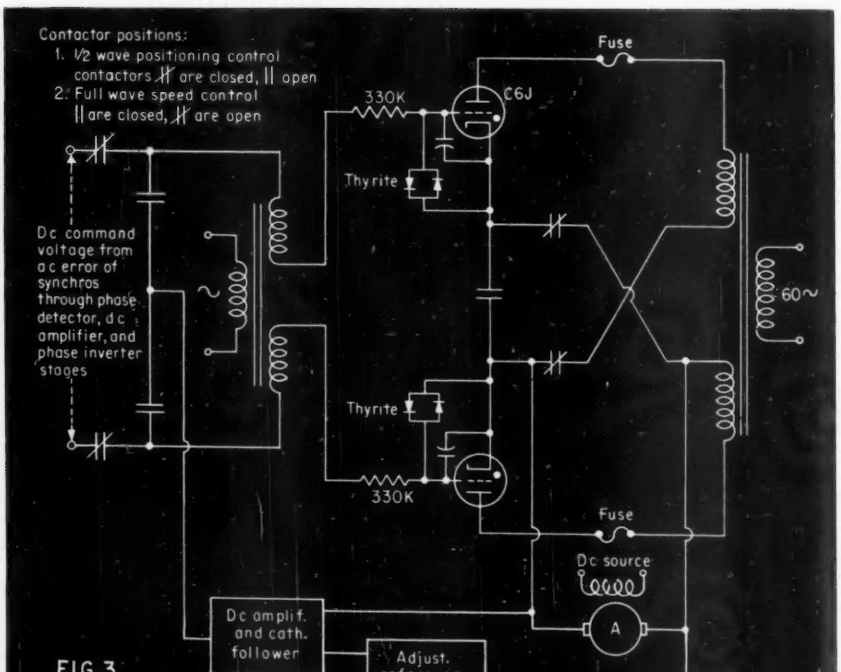


FIG.3

THYRATRON SERVO AMPLIFIER AND SPEED REGULATOR FOR SEARCH RADAR ANTENNA

RATE OF CHANGE OF AC ERROR VOLTAGE FOR STABILIZING CONTROL OF SEPARATELY-EXCITED DC MOTORS

FIG. 4. An interesting application of thyratron servos occurs in a numerically-controlled machine tool. Stabilization is derived from the rate of change of ac error voltage. Two inverse-parallel connected thyratrons provide the power amplification for control of armature voltage of one of two ⅛-hp separately-excited dc servo motors driving the lateral and transverse motions of a milling machine table under the command of punched paper tape. The tape contains incremental displacement, sign, and rate codes. The data punched in the tape are transferred to registers which cause rate oscillators to emit pulses. These pulses drive the lateral and transverse motors which change the position of differential synchros and the resulting ac output is fed into a control transformer.

The thyratron amplifier receives its ac error signal from the control transformer through a four-stage unity gain amplifier containing a third-harmonic filter and a conventional parallel-T ac rate network. The resulting ac rate signal voltage is added to 5-volt ac bias voltages which lag the anode voltage of each thyratron by 120 deg to achieve proportional control of firing angle of one thyratron or the other. Negative dc bias is obtained by self-rectification of the grid current, which charges grid by-pass capacitors each time the grid voltage swings positive with respect to the cathode.

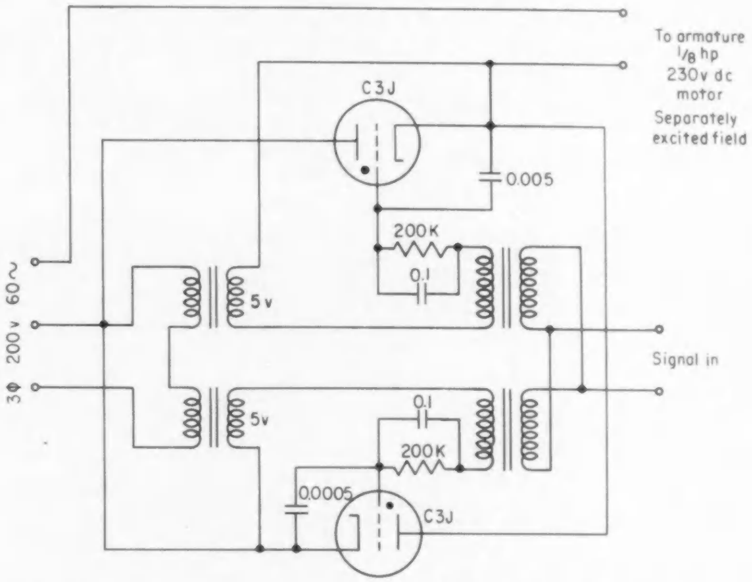


FIG. 4

Courtesy: Case Institute of Technology

NUMERICAL MACHINE TOOL CONTROL

RATE OF CHANGE OF MOTOR VELOCITY FOR STABILIZING CONTROL OF SEPARATELY-EXCITED DC MOTORS

FIG. 5. To form the desired nozzle shapes of Cal Tech's Jet Propulsion Laboratory 20-in. supersonic wind tunnel, 48 screw jacks are operated in accordance with commands from a master template. A separate servo amplifier and motor like the one shown here controls each screw jack.

Half-wave thyratron amplifiers control the direction and speed of rotation of the motor armature in the cathode circuit of both tubes, which have separate anode transformer windings. The signal applied to the grid of each 2.5-amp thyratron consists of an ac error signal from transformer T2 (which is a synchro position signal passed through three stages of vacuum-tube preamplification), a fixed ac bias voltage from T3, and a fixed but adjustable dc bias developed across the dual pots.

When the armature is at rest, or moving at constant velocity, no voltage appears across R27 and R28. However, if the armature rotates while neither tube is conducting, the back emf appears across the voltage divider in parallel with the armature. Under transient conditions this back emf changes rapidly, so that a voltage approximately proportional to the rate of change of armature velocity (hence armature acceleration) appears across R27 and R28 through C14 and C13. The acceleration signal, added to the error signal, very effectively damps the servo. This stabilization method results in essentially a zero velocity error system.

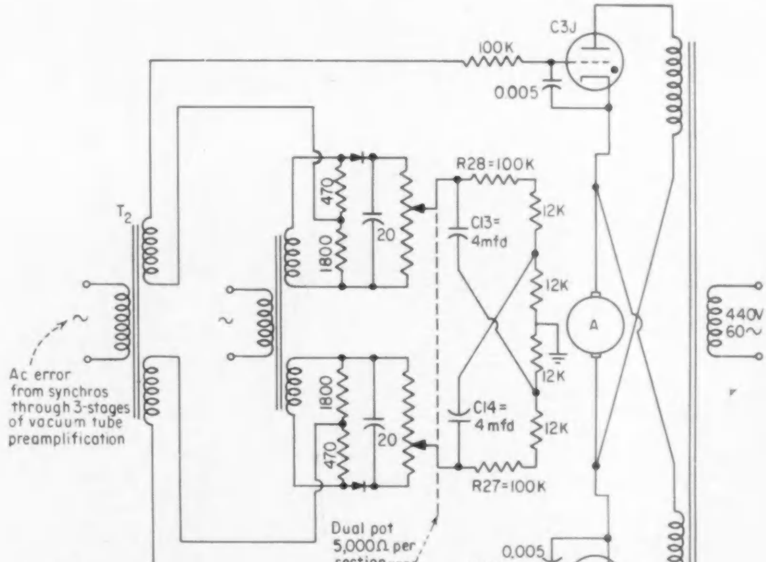


FIG. 5

Courtesy: Hanson-Gorrill-Brion, Consultants

WIND TUNNEL THROAT CONTROL

NONLINEAR STABILIZATION OF THYRATRON-AMPLIFIER SERVOS

Various nonlinear servo stabilization schemes have been proposed to minimize overshoot on correction at maximum sensitivity. In 1938 Williams described a method of kinetic-energy damping of a thyratron servo by feeding back a voltage proportional to the square of the absolute value of output velocity. The feedback voltage thus represented the kinetic energy of the servo motor and its load. Williams showed that for minimum overshoot on step inputs the voltage supplied to the motor should be reversed at a time determined by the difference between the error and the instantaneous level of kinetic energy of the motor and load. Though very successful in high-performance thyratron-powered recorders, this method was found to introduce a large velocity error in continuous tracking systems.

To overcome velocity error in a military servo, Graham[2] connected one tachometer to the master, or input, and another to the output, or slave. The instantaneous difference of these velocity voltages (V_m-V_s) was fed back to stabilize the system. Here, (V_m-V_s) equals the rate of change of error, as can be seen from the following relationships:

$$\phi_m - \phi_s = E$$

$$\frac{d\phi_m}{dt} - \frac{d\phi_s}{dt} = \frac{d\,E}{dt}$$

$$(V_m - V_s) = \frac{d\,E}{dt}$$

where ϕ_m = position of master
ϕ_s = position of slave
E = error
V_m = velocity of master
V_s = velocity of slave

This arrangement introduces no velocity error into the system.

Another method[3], using the square of the absolute value of the difference— $(V_m-V_s)^2$ —more nearly approaches optimum performance. This satisfies Williams' kinetic energy damping criterion only when $V_m=0$.

The ideal damping term is not $(V_m-V_s)^2$, however, but a term proportional to $(V_m^2-V_s^2)$. Thus, at any instant when the master and slave are not moving at the same velocity, the stabilizing voltage is proportional to the difference between the kinetic energy which the output should have at that instant (were it moving at the same velocity as the master) and the kinetic energy it does have due to its actual velocity. The two terms are equal only if either V_m or V_s is zero. The algebraic sign of each squared term is determined by the sign of the term before squaring. A stabilizing voltage proportional to $(V_m^2-V_s^2)$ introduces no velocity error.

There are many ways to obtain the square of a voltage, and thus a voltage proportional to $(V_m^2-V_s^2)$. Nonlinear voltage-sensitive resistors (varistors), with their squaring possibilities, can be used in series with fixed resistances for this purpose. Also useful for squaring voltages are cascaded biased diodes[3] and, over a limited range, a single copper-oxide rectifier[1]. Inverse-parallel arrangements of all these schemes may be used for squaring ac voltages when the output waveform distortion can be tolerated. For limited-travel systems, where tachometers cannot be used, the circuit shown in Figure 6 proves useful. The circuit separates the position-error voltage into master-and slave component voltages, differentiates them in the R-C networks to yield rate voltages proportional to V_m and V_s, squares the rate voltages in the nonlinear rectifier network, and recombines these voltages into a total voltage approximately proportional to the error plus the ideal damping factor. (Algebraic signs are determined as described previously.)

Where a tachometer may be connected to the master, as in an unlimited-travel rotary system, the master velocity voltage is immediately available and may be readily squared. The same holds true for the slave velocity signal. The two velocity squared voltages yield the stabilizing voltage, which is needed for ideal kinetic energy damping.

In some systems, however, it may be impossible or impractical to make connection to the master for the direct establishment of V_m. In these cases the desired damping voltage $(V_m^2-V_s^2)$ may be established by measuring the error and output velocity voltages, squaring the sum of the error rate and the slave velocity voltages, and subtracting the square of the slave velocity voltage alone. That this method yields the desired damping voltage can be seen from the following relationship:

$$V_m - V_s = \frac{d\,E}{dt}$$

then

$$V_m = \frac{d\,E}{dt} + V_s$$

or

$$\left(V_m^2 - V_s^2\right) = \left(\frac{d\,E}{dt} + V_s\right)^2 - V_s^2$$

Again, it is important to emphasize that the algebraic signs of the squared terms are made the same as that of the corresponding terms before squaring.

Dual-mode control

Recent advances in the nonlinear servo field indicate that optimum system performance can be ob-

tained in practice with dual-mode operation. For small values of position error and velocity the system operates linearly (it is equivalent to linear operation in a small area around the origin of the phase plane[4]). For larger errors full restoring torque should be applied to the load first in one direction and then in the opposite direction at the correct instant to bring the load to the zero-error position in the shortest possible time without overshoot. Stated another way, for large corrections full current of one polarity (or phase) is applied to the motor to drive it in the correcting direction. At some time before zero-error is reached the controller reverses the direction of current to the motor, but because of the stored inertia in the load the motor continues to rotate in the original direction. In this manner the reversed current dynamically brakes the load and brings it to the zero-error position in the shortest possible time. At this position the stored energy is completely used up and the motor receives no more power. The system remains in this zero state until another input change effects another correction.

Thyratron amplifiers are ideal for such dual-mode servo system operation since they are readily controllable as linear proportional amplifiers (to correct for small errors) and as on-off contractors (to correct for larger errors). Combining error and stabilization voltages, as well as switching between linear and nonlinear operation, are easily accomplished in the thyratron's low-power grid circuit by vacuum tubes, biased diodes, or transistors, without the need for any moving contactors.

Near optimum control and stabilization with thyratron amplifiers can be obtained if the position error voltage, after preamplification, is limited to that magnitude E_L which just fully turns on one set of thyratrons and if to this limited error voltage is added the ideal kinetic energy stabilization voltage. Thus, the total signal voltage e_c seen at the thyratron grid equals

$$E_{limited} + k(V_m^2 - V_s^2)$$

with algebraic signs of the last term determined as previously explained. The proportional factor k accounts for the load and motor inertia of the system. The greater the inertia the greater will be k; thus the stabilization voltage can be adjusted for dynamics of the particular system.

The above equation can be used to illustrate how a typical thyratron-controlled dual-mode servo operates. For small errors, when e_c does not exceed the full turn-on voltage, the system corrects proportionally for these small errors. For large errors the thyratron amplifier operates first as an on-off programmed controller to diminish these errors as fast as possible; then, when the error becomes small enough (less than the full turn-on voltage) the controller operates in the proportional mode.

The thyratron controller automatically programs the time at which the input current to the motor should be reversed to bring the system to zero error without overshoot in minimum time. For a large sudden change in input position initially the algebraic sign of the ideal damping term is such that it adds to that of the position error term. The grid then sees a full-on correcting signal. When the velocity of the slave exceeds that of the master the algebraic sign of the damping term changes and braking starts. When the master has reached its new position, the grid signal voltage is determined by the squared slave tachometer voltage alone as long as it exceeds the limited error voltage. Thus, the reversing tube is turned full "on", and the forward tube is turned "off" during this braking period. As the slave velocity decreases, the sign of the grid signal again becomes dependent on position error. As soon as e_c becomes less than that magnitude required to turn one set of thyratrons full "on", the system operates in the proportional mode.

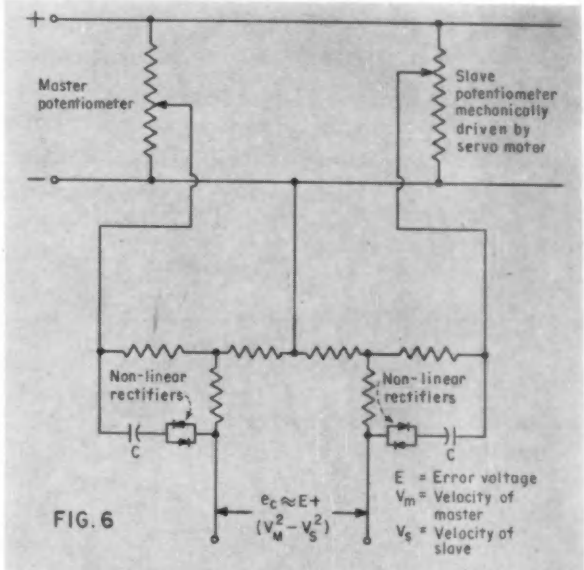


FIG. 6

NETWORK DEVELOPS VOLTAGE FOR FEEDING BACK POSITION ERROR AND KINETIC-ENERGY DAMPING SIGNAL

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Adjustable Speed Drives: Key to Dynamic Materials Handling

It has been estimated that as much as 50 percent of the total cost of some manufactured products goes into handling. Since most of these handling operations cannot be eliminated, it behooves manufacturers to automatize them for maximum efficiency. It is no longer enough to merely transport the material or object from one point to another. The materials handling system must be a coordinated, integrated part of the overall plant system, and must work in rhythm with it.

Adjustable speed drives are the building blocks for coordinating a materials handling system with the manufacturing process it serves. Though sometimes hard to justify immediately, the more complex drives may soon pay for themselves because of their versatility: they contain all the elements necessary for integration of handling and processing by feedback control.

This article compares important features of the commercially available types of adjustable speed drives. It also discusses the special drive requirements of several basic materials handling systems in common use: grab bucket hoists, skip hoists, cranes, bulk conveyors, production conveyors.

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Three basic classifications of adjustable speed drives are electrical, mechanical, and hydraulic. The first two are most common in materials handling.

MECHANICAL

The mechanical speed-ratio changer finds its principal materials handling application on small production or warehousing conveyors, where low cost and simplicity are the primary considerations. It usually has a limited speed range (generally about 3:1), and speed is usually manually adjusted by means of a handwheel or knob. Pilot-motor control is available where remote control is required, and is sometimes used with feedback controls. This may not be satisfactory in every application, since it is normally an "on-off" control and not an error-proportional feedback control. Although speed range and flexibility are rather limited in the mechanical speed-ratio changer, it serves a definite need for a simple, low-cost, adjustable speed drive.

ELECTRICAL

There are three basic types of electric adjustable speed drives used in materials handling applications: (1) The adjustable-voltage or Ward-Leonard drive wherein an adjustable dc voltage (usually supplied by a field-controlled motor-driven generator or an electronic adjustable-voltage rectifier) is applied to the armature of a dc shunt-wound motor or motors. (2) The eddy-current coupling type of drive wherein an eddy-current coupling is mechanically connected between a squirrel-cage induction motor and the load, and output speed is determined by the excitation applied to the eddy-current coupling control winding. (3) The ac commutator type motor which is controlled by positioning the commutator brushes.

The ac commutating motor is usually controlled by a speed-control knob on top of the motor frame. But it is also available with a pilot-motor mechanism for adjusting speed, and can be incorporated into feedback systems. Once again, however, the pilot-motor control is usually an "on-off" control, not proportional, and, generally speaking, has the same limitations as a mechanical speed-ratio changer.

The eddy-current coupling drive without a feedback regulator is inherently an adjustable varying-speed drive. However, used with a feedback regulator, it takes on adjustable speed drive characteristics. Its efficiency at low speed is not too good since the losses dissipated in the coupling as heat are approximately inversely proportional to output speed.

The adjustable-voltage dc shunt motor inherently has sufficiently good speed regulation to be satisfactory for many materials handling applications with-

SOME DEFINITIONS

The term "adjustable speed drive" is pretty much taken for granted. Thus, it might be well to draw a contrast between "adjustable speed drives" and "adjustable varying-speed drives". An "adjustable speed drive", for the purposes of this article, is one whose speed can be adjusted gradually over a considerable range, but, once adjusted, remains practically unaffected by load changes (say 15 percent or less change in speed as load changes from no load to full load). An example of an adjustable speed drive is a shunt-wound dc motor with armature voltage or motor field control (assuming the motor has been designed for the speed range by field control).

On the other hand, an "adjustable varying-speed drive" is one whose speed can be adjusted gradually but, once adjusted for a given load, varies considerably with changes in load. An example of an "adjustable varying-speed drive" is a slip-ring motor with secondary resistance control or an eddy current coupling type of drive without a feedback speed regulator (see Figure 1).

Another commonly used classification is "multi-speed drive"; here the drive has two or more distinct selectable speeds which remain relatively constant independent of load changes. This type of drive is neither adjustable speed nor adjustable varying-speed since its speed cannot be gradually adjusted. However, it is more nearly like the adjustable speed drive since its speed is not materially affected by changes in load.

These definitions are not the only accurate definitions which could be given for these drives, but should convey some understanding of what is meant by these terms. This article is primarily concerned with "adjustable speed drives" as defined above.

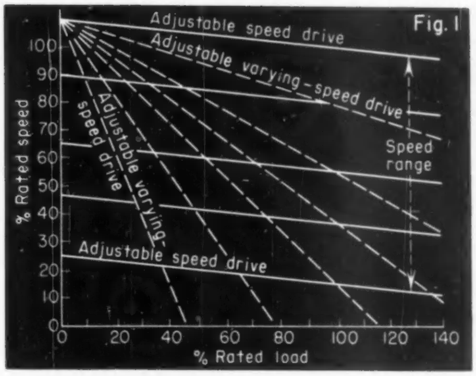


Fig. 1

TYPICAL ADJUSTABLE SPEED DRIVE CHARACTERISTICS

DRIVE TYPE	CONTROL MEANS	USUAL SPEED RANGE	FEEDBACK	RELATIVE INITIAL COST SEE NOTE 1	REMARKS
MECHANICAL SPEED RATIO CHANGER	manual	3:1 (up to 10:1 available)		(1) lowest	simplest
	pilot motor		"on-off"	(1.1)	
ELECTRICAL AC COMMUTATOR MOTOR	manual	3:1 (up to 20:1 available)	–	(1.3) intermediate	brush shifting motor
	pilot motor		"on-off"	(1.4)	
EDDY CURRENT COUPLING	coupling control field voltage	10:1	proportional	(1.4)	poor efficiency at low speeds; almost always closed loop control
ADJUSTABLE VOLTAGE DC SHUNT MOTOR	armature voltage	8:1	proportional	highest (1.5)	constant torque characteristic
	motor field voltage	20:1	proportional	(1.5)	constant horsepower characteristic

NOTE 1: Because of the many possible circuit arrangements, no exact cost relationship can be stated. The numbers in parentheses are for typical commercial systems. Particular applications may vary markedly.

NOTE 2: Response times of most drive systems range from one to several seconds; are not usually a limiting factor in materials handling applications.

out a feedback regulator. However, it is very easily adapted to feedback systems where requirements make it necessary. The shunt-motor speed can also be controlled by motor field control. However, the drive characteristic here is constant-horsepower, not constant-torque, which the great majority of materials handling applications demand.

Both basic types of electric adjustable speed drives have a higher initial cost than the mechanical speed-ratio changer, but this is offset by the formers' ease of control, wide speed range, high degree of flexibility for feedback control or programming, and accurate speed control. The various drives are compared in the table on typical drive characteristics.

To these general aspects of applying adjustable speed drives to materials handling equipment should be added the literally hundreds of particular drive requirements, each inherent to the type of materials handling equipment considered. The more important drive characteristics needed by materials handling systems can be illustrated by several typical applications.

REQUIREMENTS OF TYPICAL APPLICATIONS

GRAB BUCKET HOISTS

There are a number of types and variations of grab bucket hoists used to handle bulk materials such as iron ore and coal. Consider one of the more common types, the "holding and closing line" arrangement. Figure 2 illustrates the reeving commonly used for a holding line/closing line combination. The open bucket is lowered into the ore or coal pile, where it is closed by taking in rope on the closing drum. When the bucket is closed, the holding line and closing line drives are operated simultaneously to take in the rope on both lines and to hoist the bucket. During the hoisting operation, it is essential to divide load properly between the hold and close lines to keep the bucket from cracking open and to prevent overheating of either motor due to unbalanced loads.

When the bucket has been hoisted and relocated over the point where it is to be dumped, rope is paid out on the closing line to dump the load.

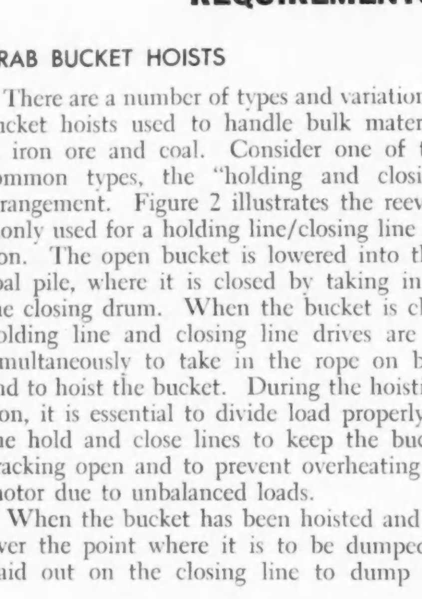


FIG. 2. Schematic of hold and close line bucket hoist.

Moving back over the original pile, the operator then simultaneously operates both the holding and closing line drives to lower the bucket. The bucket must be open as it falls to dig into the pile. If the closing line was paying out slower than the holding line, the bucket would begin to close. If the close line was paying out faster than the holding line, the closing line might snarl. Admittedly, speed-matching need not be accurate because hoisting distances are usually short, but a speed-matching control of some kind between the drives is very desirable.

Since this type of hoist is very often operating on a tight time cycle, fast response is important.

The mechanical equipment usually represents an investment of several hundred thousand dollars, so the drive should be designed for smooth acceleration and deceleration to minimize shocks. Attention to this effectively reduces mechanical maintenance.

Study of these requirements has led to the wide use of adjustable-voltage drives for the hold and close lines. Each drive consists of a shunt-wound dc motor powered by a separately excited dc generator. The generator shunt field is excited by a *multi-field* rotating amplifier (amplidyne). By using several control fields (usually four), it is possible to provide all of the above required features. Figure 3 is typical of the basic circuit employed. The reference field (F4-F5) establishes the voltage (or speed) at which the drive is to operate. A voltage feedback from the generator armature through field F3-F4 causes the voltage to be regulated at the level established by the reference. In addition, the same field F3-F4 is used to limit the maximum armature current to a predetermined value during acceleration.

Current limit

Since motor field excitation is held constant, the current-limit feature is in effect a "torque limit". During acceleration and deceleration, the torque of the drive rapidly (less than a second) rises to and is maintained at this torque limit. Consequently, the average torque during acceleration is much higher than for the same peak torque on a constant potential rheostatic control. For example, if the average torque required during acceleration was 150 percent of rated motor torque, the current limit would be

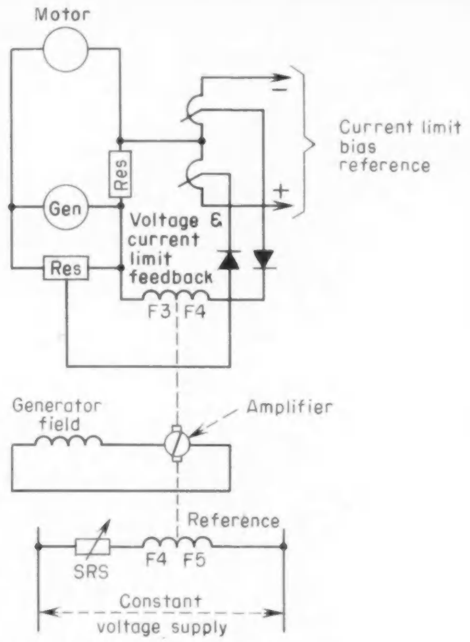


FIG. 3. Adjustable-voltage drive.
Voltage regulator with current limit control.

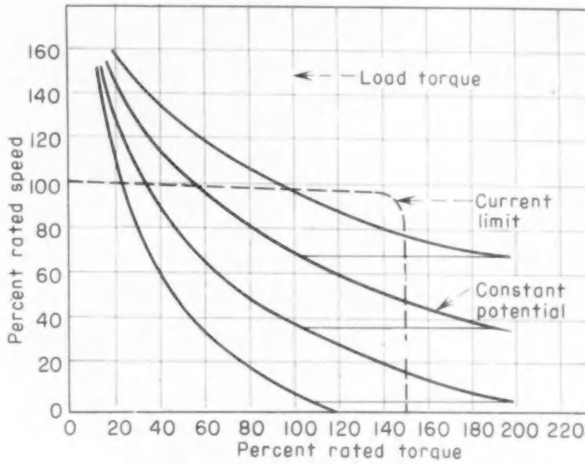


FIG. 4. Speed-torque characteristics of constant-potential control and current limit control.

set at this value. However, if an equivalent average accelerating torque were required from the constant potential drive, torque peaks of 200 percent or higher would be needed to obtain an average of 150 percent torque because of the familiar saw-tooth characteristic. This is illustrated by Figure 4, where the dotted line is the characteristic with current limit control and the solid line represents the constant potential drive characteristic. Maintenance records indicate that elimination of the sharp torque peaks and consequent shock encountered with a constant potential drive very materially reduce mechanical maintenance and increase expected cable life.

Load dividing

Another field on the amplifier, not shown, provides load-dividing and speed-matching characteristics. When speed matching is required, the counter emfs of the two motors are compared and the resulting error signal fed back to correct the voltage of the appropriate generator. When load dividing is required, the voltage drop across two armature circuit resistors is compared and the voltage of the appropriate generator corrected.

Response

The rotating amplifier inherently has fast response (< 0.2 sec), and this, coupled with the forcing effect of the gain in the feedback system, permits very good overall drive response. (Acceleration from standstill to full speed in 2 to 3 sec is quite common).

Efficiency

As can be seen from Figure 3, large power contactors and banks of accelerating resistors are not required with the adjustable voltage drive. This materially reduces the maintenance on the control equipment and eliminates the sizable amount of power loss in these resistors during acceleration and deceleration. Also, during regenerative conditions the regenerative power is pumped back into the power system for use elsewhere; in the constant-potential system most of this power is dissipated and lost as heat in the resistors. Records from one installation indicated that the "power consumption per ton of material handled" for an adjustable voltage equipment was approximately 50 percent of the "power consumption per ton" of a constant potential equipment at the same installation.

Initial cost of the adjustable voltage drive is greater than for a constant potential drive (see table on drive characteristics). However, when due consideration is given to the reduced maintenance, lower power consumption, smoother control, and reduced operator fatigue allowed by the adjustable voltage drive, the added cost can frequently be justified.

SKIP HOISTS

Blast furnace skip hoists have many of the same requirements as the bucket hoist. Here, however, reliability is extremely important since the hoist is the only way to charge the raw materials into the furnace. This has led to a two-motor, two-generator armature circuit illustrated in Figure 5. There are two separate m-g sets, two motors, and two rotating amplifiers (one spare). The two motors are mechanically coupled to two separate shafts on the hoist machine gear reducer. Therefore, if any motor, generator, generator drive motor, or rotating amplifier should fail, it is possible to switch to a single-motor, single-generator arrangement, and operate at reduced capacity (usually about 75 percent) until the other drive can be put back into service. This duplication of equipment is frequently carried back through the m-g set starter and distribution system to the main

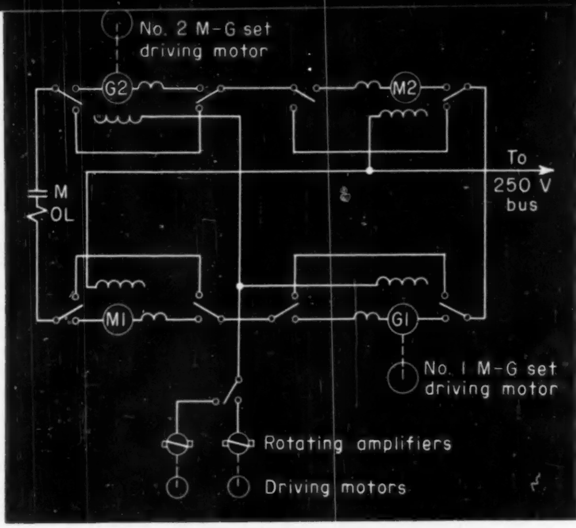


FIG. 5. Motor and generator armature circuit for skip hoist drives shows duplication of equipment for maximum reliability.

power source. With the series loop circuit shown in Figure 5, the load dividing control for bucket hoists is not required for the skip hoist drive, since the same current flows in all machines.

CRANES

In many crane applications today, increased importance is being placed on smooth, gentle control of the hook. On many cranes, accurate spotting of the load is also essential. It is doubly important, therefore, that the speed-load characteristics of the drive be flat. In other words, it is desirable that hook speed remain constant on a particular master switch speed point, irrespective of load.

For years it has been recognized that an adjustable voltage drive was the solution to these problems. But it is only recently that adjustable voltage drives have become competitive in price with other ac systems capable of good results on these applications.

Since the expense of a regulating system cannot usually be warranted for a crane hoist, some other means of controlling the rate of rise of generator voltage was necessary. One solution might have been to design the generator-field time constant to limit the rate of rise of generator voltage, but this would have been expensive since each crane might require a different time constant, and might have hampered adjustment in the field. A common scheme is to provide a damping motor in the generator field circuit for easy adjustment (Figure 6).

Once again, the adjustable voltage drive eliminates large dc power contactors, materially reduces maintenance, and (almost invariably) allows fewer collectors between the crane trolley and bridge.

The speed-load characteristics of the standard nonregulated adjustable-voltage hoist drive are quite flat and give excellent performance for spotting loads (see Figure 7). Furthermore, speed characteristics can be adjusted easily in the field by small adjustable resistors on the control panel. Contrast this to the relatively clumsy and difficult job of moving power cables on a secondary resistor for

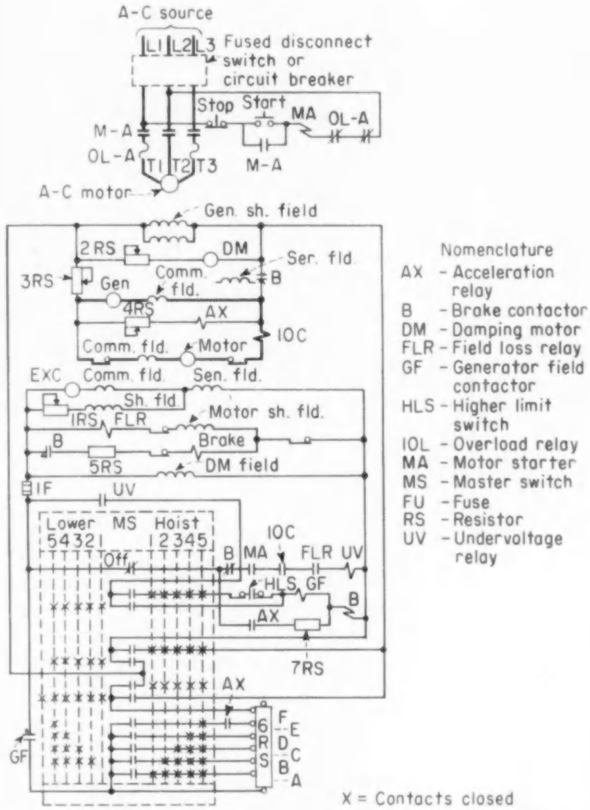


FIG. 6. Adjustable voltage shunt motor drive for crane hoists uses a damping motor to control generator field build-up.

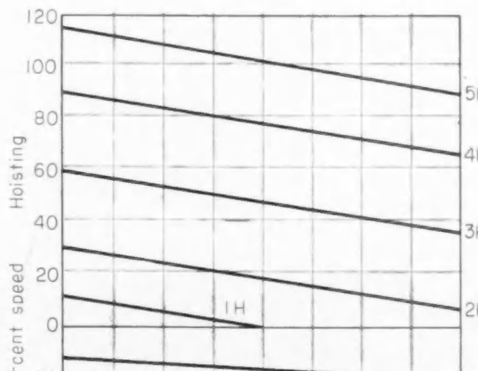


FIG. 7. Speed-load characteristics for drive of Figure 6.

a wound-rotor motor control. Many cranes do not require these refinements, but this is becoming the exception rather than the rule.

BULK HANDLING CONVEYORS

In the past, bulk handling conveyors have almost always been constant speed drives. One of the major problems in applying drives to a belt conveyor was controlling the rate of acceleration of the drive to remain within the allowable limits of belt tension and reduce slippage between drive pulley and belt.

Need is increasing for adjustable-speed bulk-conveyor drives. For example, in coal processing plants it may be desirable to adjust the speed of the conveyor to reduce degradation of the coal when it is discharged from the conveyor. And when belt-type ship-loaders are used to load bulk materials into ships, it may be desirable to control the flow into the ship, depending upon size of ship and what point in the ship is being loaded.

The two most common adjustable speed drives for bulk-handling conveyors are the adjustable voltage and the eddy-current clutch types of drive. There are two objections to the latter. As mentioned previously, in order for the eddy-current clutch drive to be a satisfactory adjustable speed drive, tachometer feedback control must be added to flatten the speed-load characteristic. Also, because bulk-handling conveyors range in drive size up to several hundred horsepower and run almost continuously, power losses can be very high if reduced speed operation is maintained for extended periods. Therefore, where long periods of operation at reduced speed are expected, the adjustable voltage drive is probably the better choice. What is more, it usually does not require a feedback regulator—the inherent regulation of a shunt motor is quite satisfactory.

There are occasions, however, where regulated systems are necessary to meet more stringent speed control accuracy requirements, to allow speed matching of two drives, or to provide some other special function. Figure 8 illustrates a system which required very close speed regulation and speed-matching of a system of conveyors.

The entire ac-driven ore stocking system is controlled by one operator at the car dumper station and is sequence interlocked. The entire dc adjustable voltage-driven ore reclaim and ship loading system is controlled by one operator aboard the ship loader, and by means of high accuracy speed matching controls between the various conveyors the system is made to function like a water hose controlled from the nozzle.

Admittedly, this is an unusual application and most bulk handling conveyor systems could not warrant such a complex adjustable speed system. Nevertheless, increased capacities and larger demand for automatic operations may make such systems commonplace in a relatively few years.

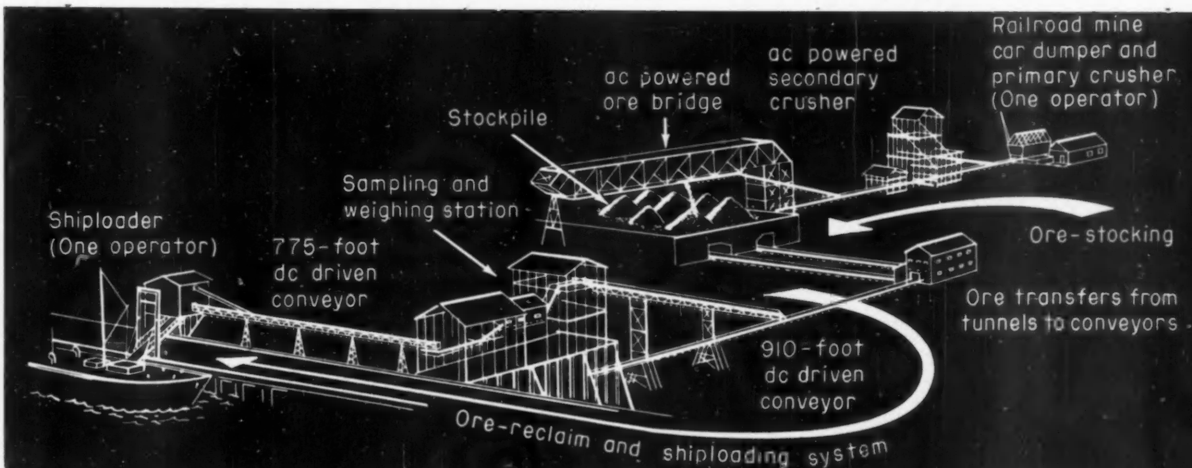
PRODUCTION CONVEYORS

Production conveyors are those which transport components, sub-assemblies, and final assemblies in a manufacturing operation. The most unusual and rapid changes are occurring in the "mass production" industries, such as automobiles and appliances.

A few years ago, production conveyor drives were almost universally constant speed; a mechanical speed ratio changer was used for speed adjustment. Today models and production rates are continually changing, and whole systems of conveyors must be synchronized to operate in perfect rhythm, so the constant speed conveyor drive is not sufficiently flexible. It is a serious matter, for example, if a refrigerator door fails to appear at the right place on the assembly line at the right time.

The mechanical speed ratio changer is still used for drives where simplicity and low initial cost are the prime considerations. However, there is a definite trend toward the increased flexibility provided by the

FIG. 8. Bulk conveyors in this ore-handling system needed tachometer feedback for accurate speed-matching.



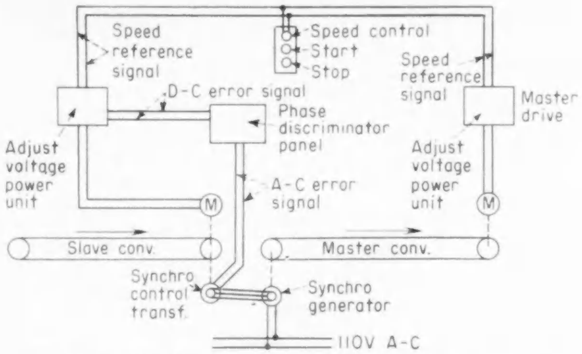


FIG. 9. Position synchronizing for production conveyors.

electric adjustable speed drive, even though that flexibility (for feedback control, programming, etc.,) may not be needed immediately.

Electric adjustable speed drives provide smooth, controlled acceleration by controlling the rate of build-up of generator field excitation, or by current limit control. This reduces conveyor maintenance and minimizes swaying from overhead conveyors. These drives lend themselves well to control from small, low-power signals, making them ideal for remote control or for regulated systems such as speed regulators or position synchronizing control. Considering that the electric drive equipment usually comprises only 2 to 5 percent of the total cost of the conveyor, the increased initial cost of the adjustable speed drive is not too great.

FEEDBACK CONTROL

The advantages and refinements of feedback control have already been discussed in relation to bucket hoist and skip hoist drives. These feedback systems were generator voltage regulators with overriding current limit control. The bucket hoist regulator also included a speed-matching or load-dividing regulator, depending upon operating conditions. The bulk-handling conveyor system of Figure 8 was also tied together as a system by means of tachometer feedback control.

On production conveyor systems there are a number of types of feedback control systems used. The electronic adjustable voltage drive, for example, is almost always a regulated drive. It normally consists of a voltage regulator, frequently with IR compensation, and current limit control, and consequently these drives usually have excellent speed-load characteristics. As was pointed out earlier, the eddy-current clutch type of drive must also be a regulated drive to qualify as an adjustable speed drive. Here feedback is from a tachometer generator, usually mounted on the drive motor.

Tachometer feedback control is frequently used on production conveyor drives which require close speed control, such as ovens and paint lines. Tachometer follower drives are also widely used in this field to speed-match a whole system of conveyors. In a tachometer follower control system, the reference for the "slave" drive is provided by a tachometer generator which measures the speed of the "master" drive. Usually, the slave drive has either a speed or voltage regulator to enable it to follow the master drive with reasonable accuracy.

Position-synchronizing is another feedback system which finds wide use in assembly or testing operations. Synchronized transfer of parts or assemblies from one conveyor to another is one such operation. When a unit passes the transfer point on the feeding conveyor, it is essential that an empty dog or hook on the receiving conveyor pass the same point ready to receive the unit. A "test harness" operation also creates a need for position-synchronizing. The harness is suspended from an overhead conveyor and connected to a unit being tested on a floor conveyor. Position-synchronizing allows testing with the conveyors in motion.

Figure 9 shows schematically how two conveyors might be position-synchronized. A speed potentiometer provides the same reference signal to both the master and slave drive, causing them to run at the same general speed. However, without some further control the speed error between drives would be cumulative and the two positions on the corresponding conveyors would gradually pull apart. To prevent this, a synchro generator is geared to the master conveyor, and a synchro control transformer is geared to the slave conveyor. The two synchros are then electrically connected so that any physical displacement of the rotor of one synchro with respect to the other will cause a voltage proportional to this displacement to appear at the output terminals of the control transformer. This voltage, representing the position error between the two conveyors, is fed into a phase discriminator, which converts it into a polarized dc voltage. This new voltage is then superimposed on the reference signal to the slave conveyor to speed up or slow down the slave conveyor, as required, to maintain position-synchronism between the two conveyors.

OTHER TRENDS IN MATERIALS HANDLING CONTROL

The trend to adjustable speed drives and feedback control is closely related to the industry-wide movement to more automatic control in manufacturing operations. No mention has been made of the increasing attention to such things as memory systems, programming, static switching, and punched and magnetic tape controls. These are existing, well-established techniques, and it is now simply a matter of refining the technology to allow practical and economic application to industrial materials handling systems.

Automatic program controls using telephone relay and stepping switch circuits have been used very successfully on blast furnace charging systems for a number of years, and there is now every indication that these controls will be expanded to handle other operations around the furnace. Warehousing systems and order accumulation systems requiring memory control are also natural applications for static switching and tape control techniques.

RELIABILITY OF REDUNDANT SYSTEMS

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System reliability is of great concern to control engineers in all industries, particularly in aircraft and ordnance. Even with the most conservative approach —improving reliability of each component—the improvement necessary is radical, and it may take some time. Meanwhile, however, redundant components and subsystems can provide better reliability.

These charts for the control engineer's data file evaluate the reliability of series and parallel arrays. Similar charts in CDF-3 will cover series links in parallel and parallel groups in series. CDF-4 and CDF-5 will treat decision-switching devices connected in typical combinations. Note that although all the charts were devised to study redundancy, they are also useful for evaluating the reliability of any system, redundant or not, that has components and subsystems so arrayed.

The reliability values, P_s, indicated in the charts are the maximum possible. They do not reflect the degradation that will occur in specific applications. The user should exercise his judgment in the light of these considerations:

1. Will failure of any component or subsystem affect the others?
2. How much will redundancy increase weight, space, and cost and maintenance?
3. How about added complexity?
4. Will concealed component failures require special testing techniques to locate faulty parts and assemblies?

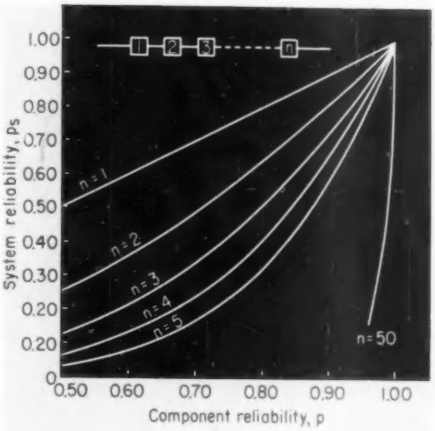


FIG. 1. System reliability as a function of n independent components connected in series.

Let p_i = reliability of i^{th} component. $i = 1, 2, \ldots\ldots, n$.

Since the system fails when one or more components fail, the reliability of the system is

$$P_s = p_1 \cdot p_2 \cdot p_3 \ldots\ldots p_n$$

If the components are equally reliable, then $P_s = p^n$

COMMENTS:

1. Maximum system reliability requires:
   a. Maximum component reliability;
   b. Minimum number of components.
2. Since the state of the art limits component reliability and system requirements determine the minimum number of components, system reliability is limited.
3. System reliability is less than, or at best equal to, the reliability of the least reliable component.

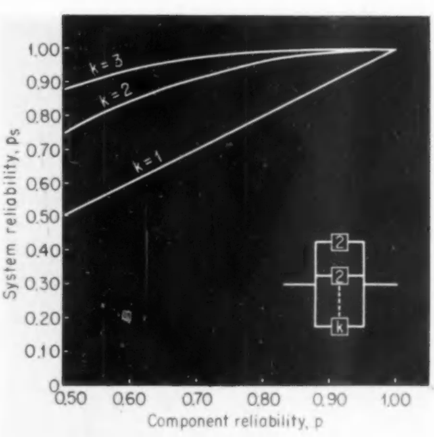


FIG. 2. System reliability as a function of k independent components connected in series.

Let p_i = reliability of i^{th} component. $i = 1, 2, \ldots\ldots k$.

Since the system fails only when all the components fail, the reliability of the system is

$$P_s = 1 - (1 - p_1)(1 - p_2) \ldots\ldots (1 - p_k)$$

If the reliability of the components is equal, then

$$p_s = 1 - (1 - p^k)$$

COMMENTS:

The reliability of the system is larger than, or at least equal to, the reliability of the most reliable component.

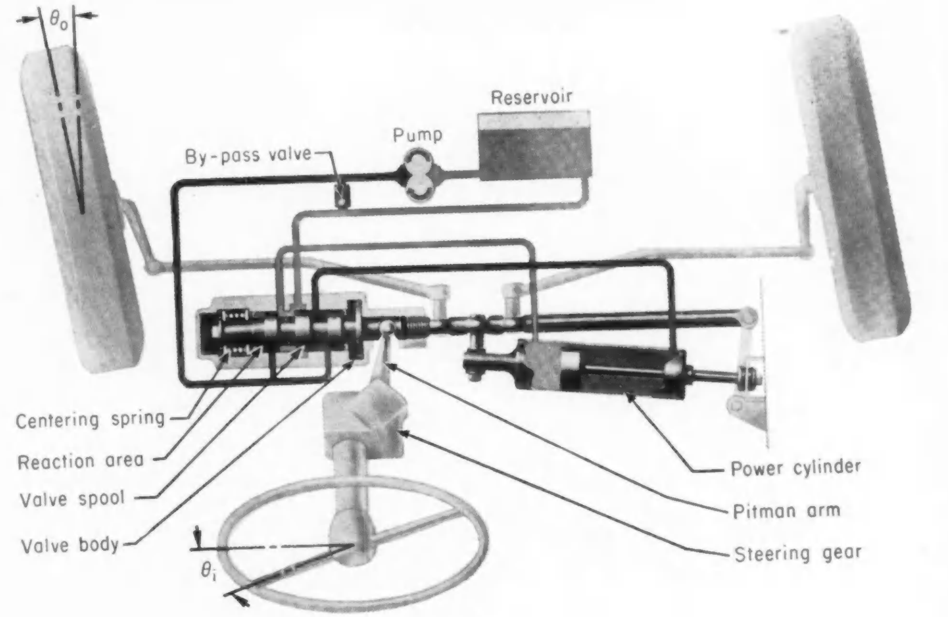


FIG. 1. Linkage-type power-steering system.

A Servo Performs for the Public*

W. E. McCARTHY and W. A. VAN WICKLIN, Ford Motor Co.

Hydraulic power steering, probably the most advertised servomechanism on the market today, is a feedback control system in which the driver closes the loop. As operator of the servo, the driver must sense the directional error and then furnish the controller with the input command necessary to reduce the error to zero. But the normal human operator, used to manual steering and facing the powered version for the first time, offers a problem to the systems designer. His input command to the system is biased by past experience, and not enough is known of his overall response characteristics to build suitable nonlinear mechanisms to compensate for this. Hence system design is actually a compromise between road feel to the driver and his safety requirements and reaction time. One particularly interesting aspect covered here: the effect of steering wheel inertia in "snap back" after turns.

*Based on a paper given at the 1955 ASME meeting.

Present-day power-steering gears are classified as integral and linkage types. A linkage gear appears in Figure 1, which shows a complete system, including hydraulic pump, power cylinder, control valve, and common automotive components. Simplified schematic diagrams of the two types of systems, with only their inertia loads represented, appear in Figure 2. In an integral system, the sensing device, power cylinder, and gear reducer are in a single housing (the broken line enclosure in Figure 2A).

Integral and linkage systems

The difference between the manual input torque, T_i (Figure 2A), applied to the steering wheel, and the reaction torque, accelerates the steering wheel of inertia J_i. Successive integrations yield the input angle θ_i, the steering wheel's angular position. This angle is compared to angle $N\theta_o$, and the difference between the two angles, E, positions the control valve for the hydraulic amplifier. The manual reaction torque felt at the steering wheel is transmitted through a spring of rate K to the gear reducer with torque output of T_m. Torque output of the system, T_o, is the sum of the manual reaction torque, T_m, and the torque obtained from the hydraulic amplifier, T_H. Output position is fed back through the same members to the input side of the gear reducer. The position feedback, $N\theta_o$, at this point is at one end of the reaction spring, and the input position is at the other end. The difference between these

positions is the error E, and the reaction torque is *K*E.

Linkage and integral power steering are quite similar. However, for a linkage type booster to have the same gain and road feel as an integral type, it must be provided with an extremely stiff spring, or a large hydraulic reaction area, or some combination of both. Hydraulic reaction is most often used because of the difficulty in providing such a very stiff spring in a limited space. In the linkage system, the steering wheel inertia appears N times as large to the centering spring as it does in the integral type. Consequently, recovery or self-aligning rate would be very slow unless the valve centering force was similarly increased.

An expanded block diagram of the linkage system in Figure 2A is presented in Figure 3; it consists of five principal loops:

1. Forward or main loop
2. Load loop
3. Position feedback loop
4. Velocity feedback loop
5. Reaction and manual torque loops

In the forward loop, the algebraic difference between the applied torque and the reaction torque produces an acceleration on the steering wheel inertia, J_1. The operation $1/D^2$ (D representing the differential operator d/dt) on $\ddot{\theta}_i$ is a double integration with respect to time, yielding θ_i. The pitman shaft position, θ_p, is found by dividing θ_i by the gear ratio, N. Valve spool position, X_i, is the product of pitman shaft position times pitman arm radius, R_p.

FIG. 2. Simplified block diagrams.

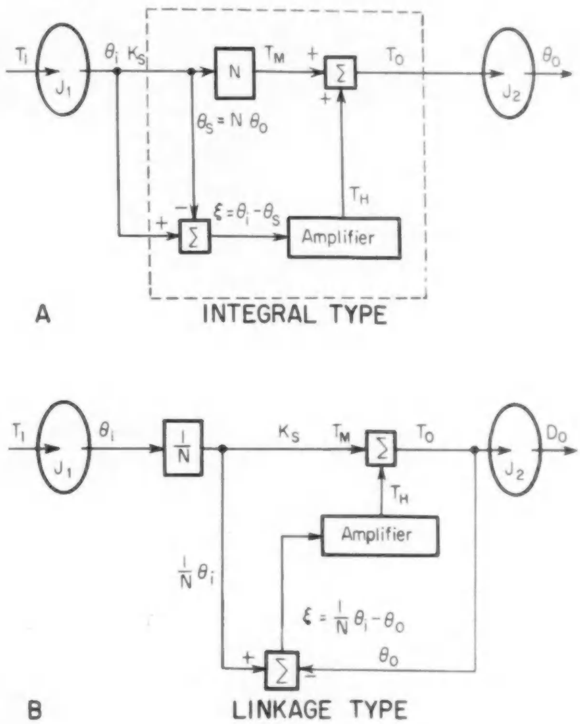
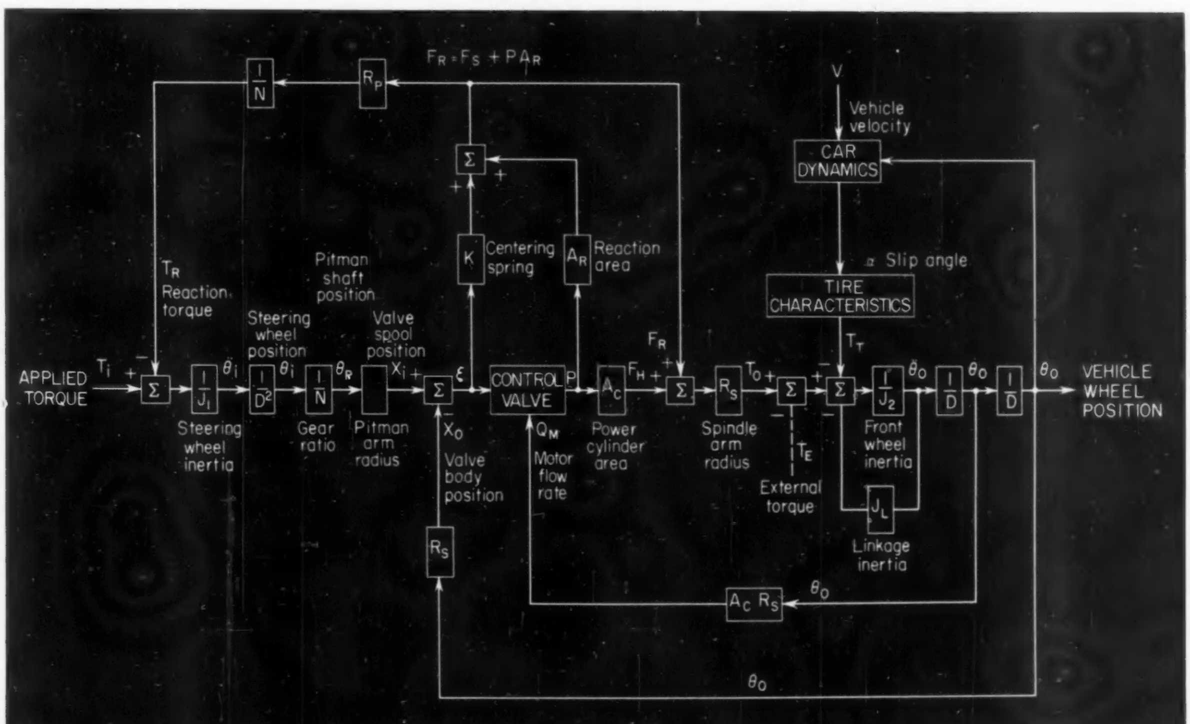


FIG. 3. Expanded representation of linkage-type system.



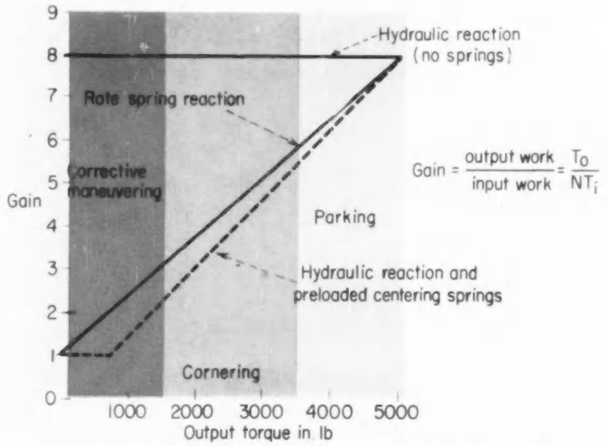


FIG. 4. Steering gain vs. output torque.

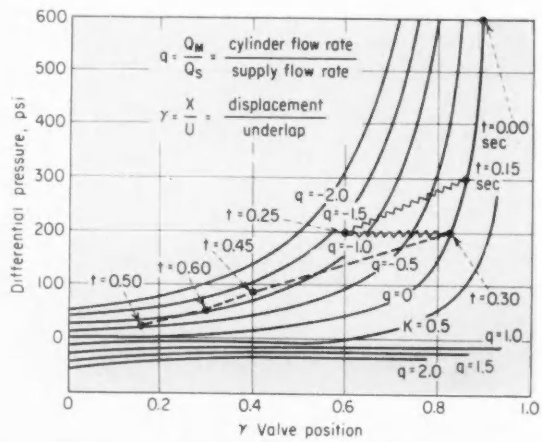


FIG. 5. Valve characteristics.

Relative motion of the valve spool with respect to valve body is the system error, E. Pressure across the piston in the power cylinder is a function of the error, E, and the flow rate, Q_m, between the valve and cylinder. Pressure P acting on the cylinder area, A_c, gives the power force F_H on the spindle arm.

The load consists of external torques about the wheel spindle, caused by wind loads and road crown, torque of the tire against the road, and the inertia loads of the steering linkage and front wheels. Difference between output torque, T_o, from the power steering gear and the road load torque, $T_T + T_E$, will accelerate the road loads $J_2 + J_L$. Integrations on the angular acceleration of the road wheels with respect to time give the velocity and position of the wheels. The angular position of the road wheels, θ_o, multiplied by the spindle arm radius, R_s, determines the control valve body position. The flow rate from the control valve to the power cylinder, Q_m, is obtained by multiplying the angular velocity of the road wheel by the spindle arm radius and by the area of the cylinder ($Q_m = \dot{\theta}_o R_s A_c$).

Steering reaction

The reaction and manual torque loops give "feel" to this controller. Opposing the system error is a centering spring and a hydraulic reaction area, both acting between the valve spool and valve body. Three types of power steering reaction, shown in the gain curve, Figure 4, can be obtained by variations in this loop. The constant gain, or full-time system, is produced when there is no centering spring force. Because the cylinder and reaction areas are both fixed, the ratio of output to reaction torque remains constant for all pressures. Preloaded spring type permits operation of the system as a manual steering gear until the reaction torque equals the preload torque. Hence, no position error exists in the system until the reaction torque exceeds the preload torque.

If the centering springs are not preloaded, any manual torque will cause some positional error and produce a pressure differential on the power cylinder. Any reaction torque back to the steering wheel reflects the same torque to the load, where it is added to the power torque from the cylinder. If both the centering spring force and the hydraulic reaction force are zero at all times, there would be a full-power system with effortless steering but without recovery. Recovery is obtained only by the reaction torque, and to increase the recovery rate, either the reaction torque must be increased or the steering wheel inertia must be decreased.

Valve characteristics

The heart of this steering-gear servo is its error detecting device—a four-way hydraulic slide valve in an open-center system. Figure 3 shows that the pressure output from the valve is a function of the valve position and the flow rate, Q_m, to the cylinder. The pressure differential, existing across the cylinder when the control valve is operating within the region of underlap, is plotted in the family of flow-rate curves appearing in Figure 5. During fast steering maneuvers the power cylinder piston may displace fluid at a rate that approaches the supply flow ($Q_m \cong Q_s$). When the required flow rate to the cylinder exceeds the supply flow rate, the pressure differential across the power cylinder is negative, opposing the piston motion, and the driver may exert greater effort than required for even standard manual steering.

This effect can be reduced by incorporating a by-pass valve in the power-steering gear, as shown in Figure 1. By opening whenever the return pressure is greater than the supply pressure, it allows some of the return oil to join the supply flow and prevents the opposing pressure differential from becoming excessive. An increase in the required flow rate to the cylinder, decreasing the pressure across the actuator, has the effect of positive damping—one of the most important forms of damping in hydraulic-steering systems.

Time lag in steering system during recovery

INERTIA LOAD	RESPONSE TIME AFTER RELEASING WHEEL (SECONDS)			
	PUMP PRESSURE	LINK CONNECTING	LEFT WHEEL	RIGHT WHEEL
NO WHEEL	0.003	0.003	0.025	0.025
30% OF STANDARD	0.020	—	0.090	0.100
40 %	0.058	—	0.140	0.160
100%	0.080	0.085	0.153	0.200
165%	0.109	0.110	0.168	0.230
218%	0.200	—	0.280	0.300

Steering-wheel inertia

Very little attention has been paid to the effect of steering-wheel inertia on servo performance. The normal steering wheel in today's car has an inertia of approximately 1.62 lb-ft^2, which may apply a torque of several pound-feet to the servo input shaft during normal recoveries. High-inertia steering wheels are less responsive to road disturbances or tire unbalance forces. Here torque attempts to position the servo valve so that it functions contrary to the demands of the cylinder, thus slowing the steering recovery and increasing the time lag in the vehicle's steering components. (Time lag is defined as the time interval between release of the input torque and the instant the system component responds.)

Typical oscillograph records showing the effects of two different steering-wheel inertias on the recovery characteristics of a moving vehicle are shown in Figure 6. The records were obtained while driving a car in a tight circle at 10 mph and then releasing the wheel for a free recovery. A 40-percent time lag is evident between the two inertia torques crossing the zero reference line. The output load is retained 40 percent longer and reduces the recovery rate from 47 to 40 deg per second.

The 90-cps oscillation in the input torque supply pressure and output load during initial recovery is the reflection of the valve's transient instability. If a few points from Figure 6 are projected on Figure 5 the valve characteristics become more apparent. At 0.15 sec, the output angular velocity is zero and the hydraulic pressure is about 300 psi. Five hundredths of a second later, the output angular velocity is 47 deg per second and the pressure is around 200 psi. Between 0.25 and 0.30 sec the velocity goes to zero momentarily and then approaches its original value. Varying the inertia load gave rise to recovery rates ranging from 150 deg per second at zero load down to 30 deg per second at 218 percent of standard inertia load (normal recovery—at 100 percent of standard load—is 45 deg per second). Time lags measured in this test are shown in the table on this page.

Data presented in the table and in Figure 6 were obtained from an integral-type steering gear using a linear rate spring, the rate spring force being directly proportional to the servo-system error. Since even a small torque, such as the steering wheel inertia torque, will produce a finite error in the servo system, adjustable preloaded centering springs are often used. They prevent the steering-wheel inertia torque from becoming a command to the servo valve by demanding a minimum input torque before the valve operates. Hydraulic reaction will also be of benefit because it increases the reaction torque which, in turn, helps accelerate the steering wheel.

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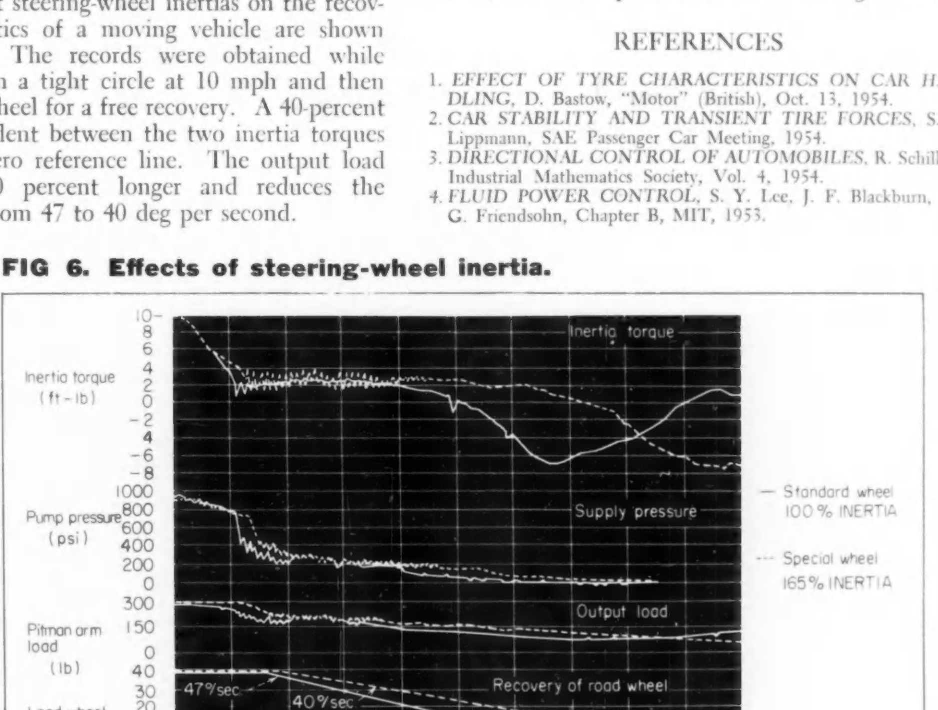
FIG 6. Effects of steering-wheel inertia.



What's Available for MEASURING MASS FLOW

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THE GIST: Volumetric flow measurement may be satisfactory for many applications, but for others mass flow measurements are needed. One such need occurs in the aircraft industry: the range capability of jet aircraft depends on the energy available in the jet fuel, and this energy is determined by weight, not by volume. The temperature extremes occurring in flight change fuel density considerably and preclude volume as a reliable measurement of available energy. Thus, the pilot wants to know how many pounds, not gallons, of fuel the plane carries and how fast, in pounds per hour, the fuel is being consumed.

Industrial applications require accurate, reliable flowmeters, too. Though this survey was carried out with the aircraft industry in view, the operating principles presented by author Gebhardt also apply to industrial flowmeters. The representative flowmeters employ many interesting principles, some—the axial-flow and gyroscopic types—yielding true mass flow, and others—the venturi, acoustic velocity, and turbine types—measuring volumetric flow and requiring density compensation to yield mass flow. The table at the right summarizes operating principles, density correction method if needed, availability and application, and manufacturer of the flowmeters described in the following pages.

In next month's CONTROL ENGINEERING Dr. J. H. Laub writes on the boundary-layer true mass flowmeter, a type not covered here. He will describe the operating principles of this method of measuring true mass flow, discuss design procedures, and present typical closed-loop control applications using electrical and pneumatic signals.

MASS FLOW MEASURING TECHNIQUES

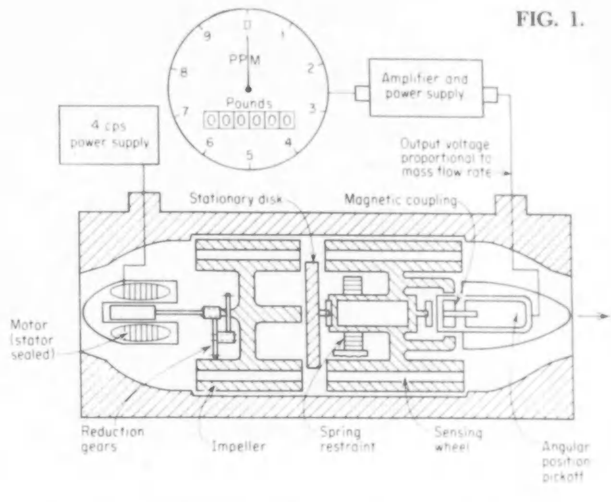
COMPANY	FLOWMETER: PRINCIPLE OF OPERATION	DENSITY CORRECTION	APPLICATIONS AND AVAILABILITY
General Electric Company	Angular momentum reaction torque (axial flow type)	None required	In use on aircraft for engine fuel flow and inflight refueling
Avien	Angular momentum reaction torque (axial flow type)	None required	In use on aircraft for engine fuel flow instrumentation
Control Engineering Corporation	Angular momentum reaction torque (gyroscopic type)	None required	In production for industrial applications
Bendix, Eclipse-Pioneer Division	Differential pressure developed by a venturi	Series of floats varies inputs. Voltage-to-differential pressure transducer	In use on tanker-type aircraft
Maxson Engineering Corporation	Measures difference in transit time of acoustic waves traveling upstream and downstream	Measures acoustic impedance, which is a function of density	Available both for aircraft and industrial use. (Fischer & Porter Co. handles industrial type)
Potter Aeronautical Company	Spinning rotor	Float type densitometer	Available for industrial use
Revere Corporation of America	Spinning rotor	Servo-balanced float coupled to vanes located upstream of spinning rotor	Available for industrial use
United Control Corporation	Spinning rotor	Float type densitometer	This company not presently active in flowmeter field

TRUE MASS FLOWMETER

Angular Momentum Principle—Axial-Flow Types—The axial-flow type of true mass flowmeter works on the principle of conservation of angular momentum. An impeller driven at a constant angular velocity imparts angular momentum to the fluid being measured. The fluid's rate of change of angular momentum as it leaves the impeller is proportional to the impeller's velocity and to the mass rate of fluid flow. A torque-sensing wheel, located adjacent to and down-stream of the impeller, removes the angular momentum from the fluid at the same rate the fluid gains momentum from the impeller. If the impeller's angular velocity remains constant, the torque on the sensing wheel is proportional to mass rate of fluid flow.

In the *General Electric* flowmeter design, Figure 1, a regulated motor-generator power supply drives the impeller at a constant frequency. The down-stream sensing wheel is spring-restrained and magnetically coupled to an angular-position pickoff. A stationary disk reduces viscous coupling between the impeller and sensing wheel at zero flow. The pickoff's output voltage, proportional to mass flow rate, feeds into a servo amplifier, a rate meter, and an integrator-counter.

FIG. 1.



This type of flowmeter is simple compared with some other methods of obtaining true mass flow, but becomes inaccurate at low flow rates, where extraneous torques exert their influence; it can measure flow in only one direction, and cannot measure rapid changes in flow.

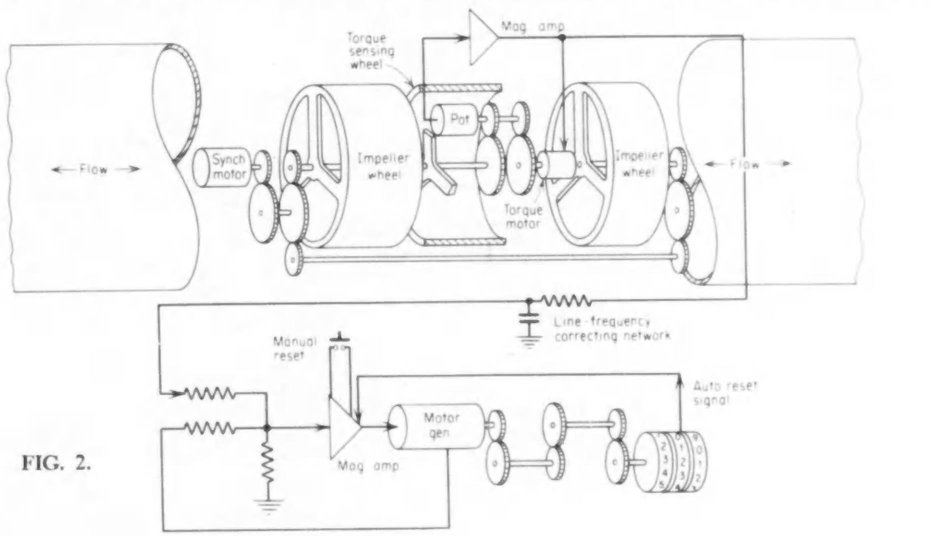


FIG. 2.

TRUE MASS FLOWMETER

The *Avien* flowmeter, Figure 2, also operating on the axial-flow principle, contains two impellers driven in opposite directions and at a speed proportional to line frequency. This arrangement permits measurement in either direction of flow in a pipe. A sensing wheel, restrained by an electromechanical torquer rather than a mechanical spring (see Figure 1), removes the angular momentum from the fluid. The torque motor providing the restraint receives an amplified potentiometer signal which is proportional to the angular position of the sensing wheel, and thus proportional to the mass flow rate times the angular velocity of the impeller.

To make the flowmeter output dependent only on the mass flow rate requires a constant angular velocity. But the angular velocity, being proportional to line frequency, varies with changes in line frequency. Such variations can be compensated by feeding the transducer output signal into a line-frequency correcting network and using the resulting output to drive a servo amplifier-recorder. When the line frequency varies from nominal the attenuation of the correcting network changes in the proper direction to compensate for the change in impeller angular velocity.

Figure 2 shows a total-flow recorder. Mass flow rate can be indicated by using a drag-cup meter. The Avien flowmeter, unlike the GE flowmeter, measures bi-directional flow. However, it has a higher pressure drop because of the restriction to flow resulting from the inclusion of the second impeller.

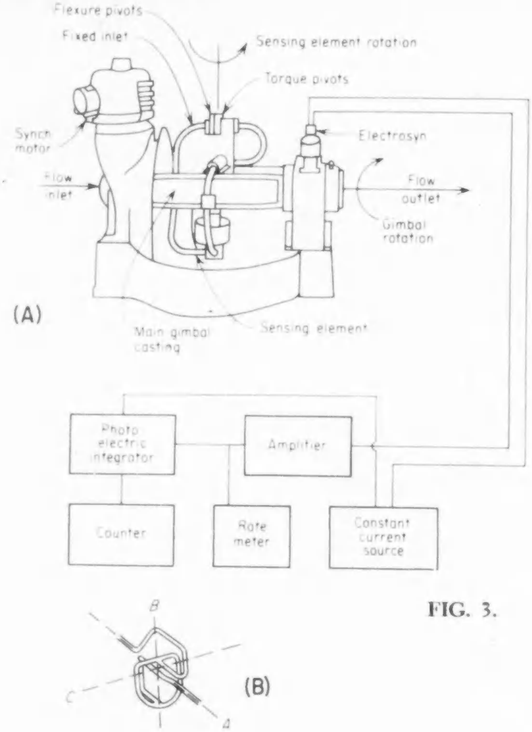


FIG. 3.

TRUE MASS FLOWMETER

Angular Momentum Principle—Gyroscopic Type—The Control Engineering Corp. flowmeter, Figure 3A, also operates on the conservation of momentum principle. Figure 3B shows the pipe configuration used as the measuring element. The flowmeter resembles a gyroscope and its operation is most readily explained in gyroscopic terms. In Figure 3B, the C axis is equivalent to a gyroscope's spin axis, fluid motion in the pipe section perpendicular to the C axis replacing the spinning wheel. The entire pipe assembly is rotated about the A axis, which corresponds to the precession axis of a gyro. The mass flow rate produces a corresponding torque about the B axis. The pipe loop parallel to the C axis corrects for centrifugal force produced when deflection occurs about the torque axis.

Flexure pivots connect the pipe elements to the sensing element. Sensing element deflection, proportional to torque or mass flow rate, is picked up by an electromagnetic rotary transducer, whose signal is carried by slip rings to an amplifier, and from there to a flow rate meter and to a photoelectric pulse former and counter to yield total flow.

This instrument has been highly developed for industrial uses, even for nonhomogeneous fluids. However, its intrinsic configuration makes it bulky.

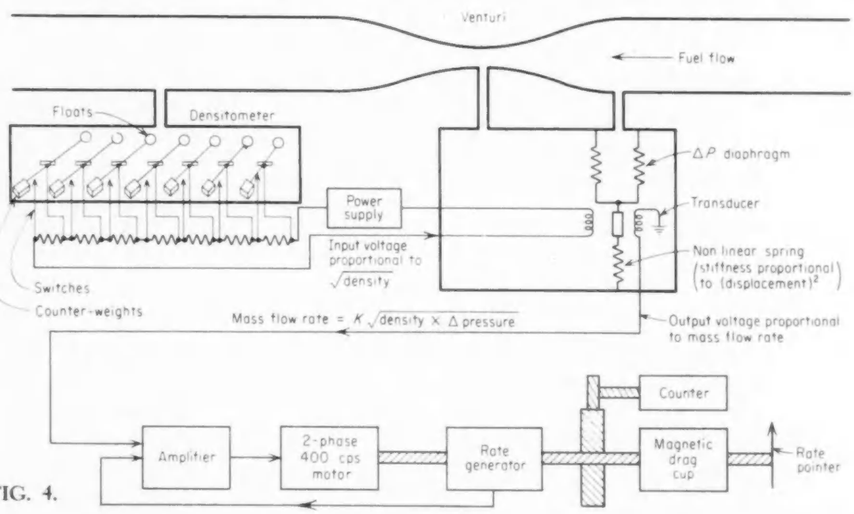


FIG. 4.

VENTURI-TYPE FLOWMETER

The *Bendix* flowmeter, Figure 4, uses a venturi as the sensing element. Since mass flow is equal to the product of density times Δp measured at the venturi, it is necessary to use a densitometer and also to correct for the square-root function. To do this, a Δp diaphragm operates against a spring with stiffness proportional to displacement squared, thus creating a displacement of the transducer core proportional to the square root of Δp. The excitation voltage for the transducer comes from the densitometer, which yields a square-root-of-density voltage depending on the number of density-sensitive float-switches operated. Because the transducer output voltage is the product of the core displacement (volume flow) and the excitation voltage (density), it is proportional to the mass flow rate. The output voltage feeds into an amplifier, drives a motor at a speed proportional to mass flow rate, operates a magnetic drag-cup rate indicator, and totalizes the flow on a counter.

The small pressure drop in the venturi and the absence of mechanical components in the flow stream are desirable characteristics of this system. However, certain other characteristics may be disadvantageous: nonlinear output, small contact pressures in the densitometer switches, and the step-type densitometer output possibly giving insufficient resolution.

ACOUSTIC VELOCITY FLOWMETER

The *Maxson* flowmeter, Figure 5, measures the velocity of fluid flow with acoustic wave-trains. It is essentially a volumetric flowmeter and therefore requires a densitometer to measure mass flow rate. Two sets of crystals (each set a transmitter and a receiver), one angled upstream and the other downstream, transmit and receive acoustic wave-trains. Each crystal set operates as follows: a short train of 10-mc oscillations from a generator is converted into acoustic energy to the transmitter, projected through the fluid, and picked up by the receiver across the tube. After being amplified, the received signal retriggers the generator and another energy train is repeated around the loop. The repetition frequency depends on the time it takes for the energy to cross the tube and on whether the signal is sent at an upstream or downstream angle.

The upstream repetition frequency is $f_1 = (v + V \cos \theta)/2d$ and the downstream repetition frequency is $f_2 = (v - V \cos \theta)/2d$; where v is the acoustic velocity, V the fluid velocity, d the distance between the transmitter and receiver, and θ the angle between the signal direction and the fluid flow direction. The beat frequency $f_1 - f_2$ equals $V \cos \theta/d$, and is therefore proportional to the fluid velocity but independent of the acoustic velocity.

Another crystal, placed in contact with the fluid, determines the density. This crystal, in series with an inductance, forms a tuned circuit, so that the voltage across it is directly proportional to the product of the density and the acoustic velocity. Dividing this product by a voltage proportional to acoustic velocity (obtained from one of the oscillating loops in which the voltage, for the fluid velocities normally encountered, is proportional to the acoustic velocity) yields a density signal.

A computer multiplies the beat frequency (velocity) signal and the density signal, so that the computer output is proportional to mass flow rate. The computer also contains an integrator. Thus, the flowmeter yields both mass flow rate and total flow.

Because the sensing element consists of a straight section of pipe, no additional pressure drop is introduced in the flow system. The Maxson flowmeter can measure a wide variety of liquids, but these liquids must not contain solids or air bubbles comparable in size to the wavelength of the acoustic wave. The electronic equipment complexity may be a limitation for some applications.

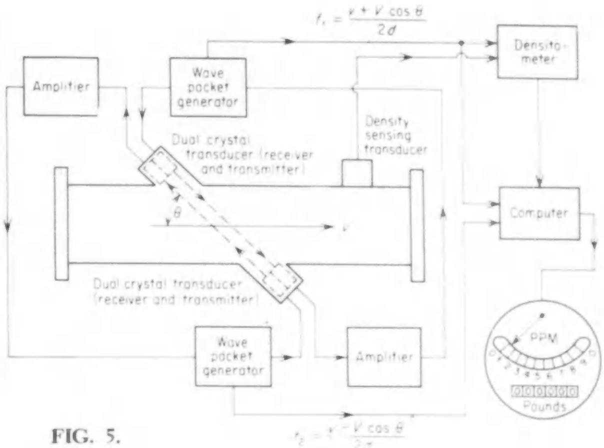


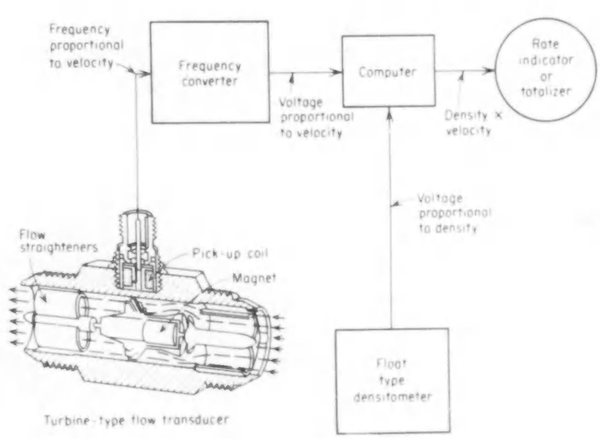
FIG. 5.

TURBINE-TYPE FLOWMETER

Simple Float Densitometer—In the *Potter* mass flowmeter, Figure 6, the familiar turbine-type volumetric flowmeter, in conjunction with a float densitometer, gives a mass flow reading. A permanent magnet in the rotor generates an alternating current in a coil located in the external housing. The generated frequency is proportional to the volumetric flow rate. An electronic converter changes the frequency signal into a dc voltage proportional to volumetric flow rate. A separate float positions an angular transducer, which produces a dc output voltage proportional to fluid density. The signals from the densitometer and frequency converter are fed to a computer, whose output is the product of density and velocity, or mass flow rate. Computer output can operate a flow rate meter or can be integrated to record total flow on a counter.

The turbine-type sensing element is available in many sizes and ranges and for many fluids. Against this advantage is the fact that the conversion of the frequency signal to dc (as required for compatibility with the dc densitometer signal) precludes direct use of the frequency signal for accurate counting.

FIG. 6.



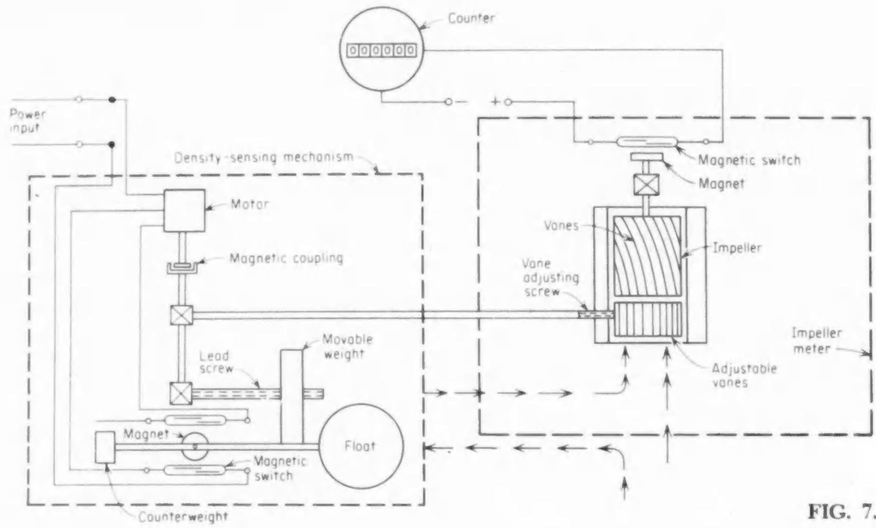


FIG. 7.

TURBINE-TYPE FLOWMETER

Adjustable-Vane Densitometer—The densitometer developed by Revere, Figure 7, provides mass flow rate measurements in conjunction with a turbine-type volumetric flowmeter. The densitometer consists essentially of a float balanced by an on-off servo-controlled movable weight. To increase sensitivity, the movable weight attached to the float is designed to hunt about the balance position determined by the density. For example, when a change in density causes the float to drop, the lower magnetic switch (lower left, Figure 7) closes and operates the motor and lead screw to move the weight to the left. This automatic weight balancing simultaneously drives a vane-adjusting screw so that the position of vanes upstream of the turbine's impeller is determined by the fluid's density.

Without the vanes the turbine is a volumetric flowmeter; with them, the turbine becomes a mass flowmeter. The vanes introduce a swirl to the fluid just before it reaches the turbine, thereby reducing the rotational speed of the turbine (for a constant volumetric flow) as a linear function of vane position. Since the vane position is proportional to density, the output of the turbine becomes proportional to mass flow rate.

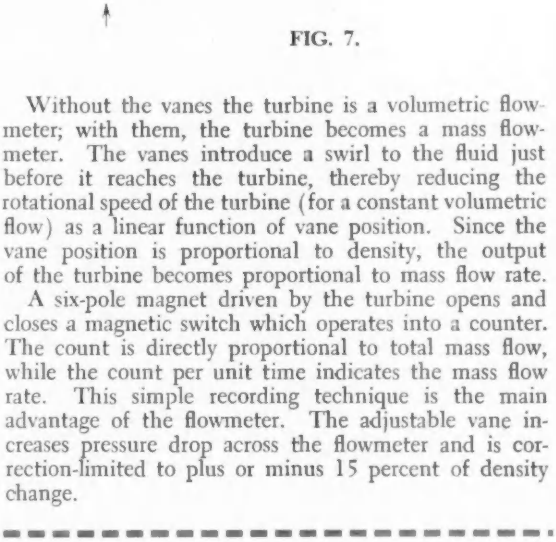
A six-pole magnet driven by the turbine opens and closes a magnetic switch which operates into a counter. The count is directly proportional to total mass flow, while the count per unit time indicates the mass flow rate. This simple recording technique is the main advantage of the flowmeter. The adjustable vane increases pressure drop across the flowmeter and is correction-limited to plus or minus 15 percent of density change.

TURBINE-TYPE FLOWMETER

Closed-Loop Servo Float Densitometer—In United Control's flowmeter (Figure 8) the impeller, whose speed is proportional to volumetric flow, generates a two-phase signal which (after amplification) drives a synchronous motor. The motor speed, a facsimile of impeller speed, then becomes proportional to volumetric flow rate. The motor drives rate and total flow indicators through variable-ratio drives. To obtain mass flow readings at these indicators, the densitometer adjusts the ratio so that the output of the drives is proportional to the product of volumetric flow rate and density.

Floats in the densitometer position a differential transformer as a function of density. A density change produces an error signal, which, after amplification, drives an induction motor. This motor positions a second differential transformer until the error reduces to zero and also adjusts the variable-ratio coupling to the indicators. A drag-cup indicator shows mass flow rate, while a counter pulsed from the commutator shows total flow. Pulse counting improves accuracy of total flow measurement. The closed-loop limits errors in the densitometer; however, drifts in transformer outputs (caused by temperature changes) could increase them.

FIG. 8.



How the Four-Tape Sorter Simplifies Storage

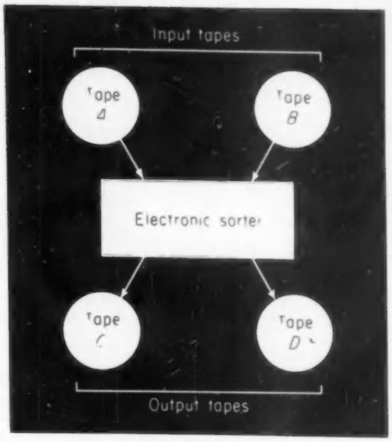


FIG. 1. Four-tape sorter.

Despite the widespread interest today in large-volume random access memory units, most data processing systems still use magnetic-tape storage for master files. To minimize access time in such systems, sorting of stored data is essential. One of the most efficient sorting techniques, and probably the fastest, is the merging-sort method described here.

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Sorting is an essential operation in electronic data processing systems that use magnetic tape for storing master files. Random searching on tape is, even at best, an inefficient process. It compares to searching for a word in a random list of words written on an ancient scroll. The new large-volume random access memories which are just beginning to appear will greatly reduce the need for sorting; they have the characteristics of a book as opposed to the scroll. But today, at least, such units cost more per digit stored than do tape systems. Since the latter are in much wider use, it follows that efficient sorting methods deserve some attention. One of the most prominent sorting techniques is the four-tape, merging-sort method.

The four-tape sorter, a specialized component of an electronic data processing system, is designed to provide rapid, efficient sorting of data stored on magnetic tape. Few manufacturers of data processing systems provide tape sorters as separate pieces of equipment. Underwood, RCA, and Marchant are a few that do. But most commercial systems require that sorting be performed by programming the computer. In such systems, as much input data as possible are put on punched cards so that the relatively efficient punched-card sorters can be used before the data ever enter the electronic system. At least one manufacturer (Datamatic) provides special sort commands in the computer to increase the efficiency of its tape sorting function.

Four-tape sorters make use of the comparison-sort, or merging-sort, technique. As illustrated in Figure 1, there are two input tapes and two output tapes. Generally, data are fed to the sorter in random sequence on a single tape. These data are passed through the sorter several times and eventually end up on one tape, in sorted sequence. After each pass through the sorter the two output tapes become the two input tapes for the next pass.

The sorter's objective is to build up ascending sequences of numbers on one of the output tapes. When an ascending sequence can no longer be continued, the machine switches to the other output tape, and starts to build up a sequence there. Each pass through the sorter results in longer sequences until, finally, one long sequence is obtained, and the information is sorted. A simple example will help in understanding the process.

Figure 2 shows two groups of numbers in random sequence on two input tape units, *A* and *B*. Although, as stated, data are usually fed in on a single tape, it is possible to feed two random tapes initially. Assuming such an input simplifies the discussion. The two numbers on top, 13 and 6, are the first two numbers in their respective tape units. The objective is to build up an ascending sequence on tape C as long as possible.

The sorter first compares the 13 and the 6 and chooses the smaller of the two, 6, transferring it to tape C, and also to a temporary register, *L*, inside the machine. A small circled 1 beside the 6 indicates this first transfer. Now the 3 moves up in tape *B* to take the place of the 6. The sorter compares the 13 and the 3 with each other, *and with the 6 which has just been transferred* (and which is also stored in L). Since the 3 is smaller than 6, it would be illogical to transfer the 3 to follow the 6 on tape C; the only choice the sorter has in this case is to transfer the

The Three Sorting Tapes

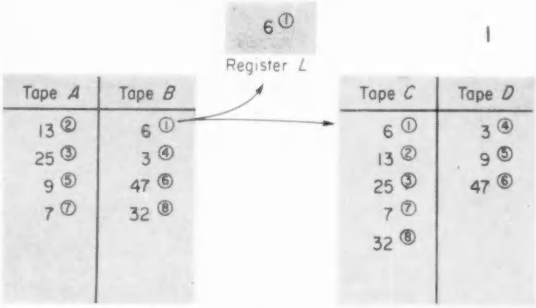

FIG. 2. First sorting pass.

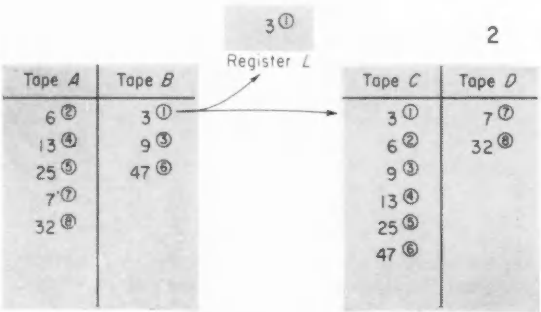

FIG. 3. Second sorting pass.

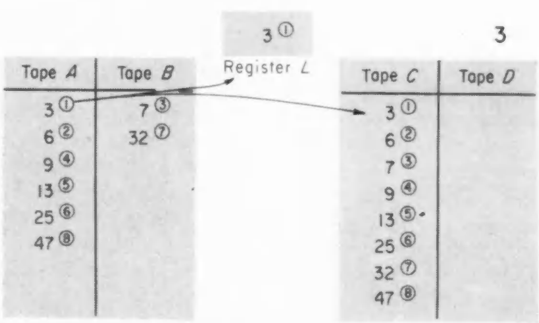

FIG. 4. Third and final sorting pass.

13, indicated by the circled 2. Next to be transferred is the 25, as indicated by the circled 3.

Then the 9 moves up to take the place of the 25. Now the two input numbers are 9 and 3. Both are smaller than the 25 which has just been transferred, so the sorter switches over to the *other* output tape, *D*. The 3 is chosen to start the sequence on tape *D*, as indicated by the circled 4. Then the 9 and the 47 are transferred to tape *D*, by the same logic. Finally, the 7 and the 32, both smaller than the 47, must be sent to the *other* output tape, in this case C.

The first pass ends after the 32 has been transferred.

On the second pass, shown in Figure 3, the two input tapes are the output tapes of the first pass. On this pass, one string of six ascending numbers is achieved while the other string is only two numbers long. Figure 4 shows the third and last pass, where all eight numbers merge in sequence on a single tape.

This simple example illustrates the major principles involved in the merging-sort method. The numbers being compared could be much longer; all that the sorter must do is find the relative magnitude of the two input numbers and the number just transferred. The numbers being compared (the sort *key*) can be just a part of the information in each item; the remaining parts would be *satellite* information that is carried along. By means of the alphabetic coding technique generally used in electronic machines, alphabetic information can be sorted in exactly the same way; in fact, this information can be sorted with numeric information at the same time.

Suppose an electronic sorter were designed as shown in Figure 5 to perform this merging-sort operation. Information would be transferred from two input tapes, A and *B*, into buffer registers in the machine. The number of digits which the buffers hold will then determine the length of the items which can be sorted conveniently. These buffers would feed directly into the arithmetic unit of the sorter, where the comparisons would be made. Two other inputs feeding into the arithmetic units would contain the last item transferred (*L*) and a set of control signals.

In operation, the sorter would feed these four signals to the arithmetic unit simultaneously, as shown in Figure 6. The three comparison circuits, operating in parallel, would simultaneously perform the three comparisons between A, *B*, and *L*. The control signals would provide an automatic extract (by means of opening and closing three gate circuits) which would allow only digits in the keys of A, *B*, and L to get through to the comparison circuits, the satellite information being ignored. For each comparison, one of two output lines would be energized; for example, $A \geq B$, or $A < B$. The same would be true for A and L, and B and L. The matrix (e.g., diodes) would decode which one of the six possible combinations existed; that is, only one of the six vertical lines would be energized (would have a signal on each of its three matrix connections), and this line in turn would energize the desired action. Thus, as soon as the three keys had been compared, proper action would be determined almost immediately. These output signals would then be fed to switching circuits, shown in Figure 5, to determine whether A or B is to be transferred, and whether it is to go to the *same* or the *other* output tape.

Special sorters of this type are often limited by tape input speed; that is, comparisons can be performed faster than numbers can be read in from tape. The time for one pass through the sorter, in this case, is just the amount of time needed to read all the information into the sorter. If 1,000 40-digit

items are to be sorted, for instance, there are 40,000 digits of information. If the tape reading speed is 5,000 digits per second (rates in commercial machines vary from 2,000 to 56,000 digits per second), this would be 8 sec for reading. To this must be added the 1,000 times (one time for each item) the tape must be stopped and started. Assuming 0.010 sec per stop-start, this is another 10 sec, or a total of 18 sec for one pass. The number of passes is approximated by the formula:

$$P = \log_2 N$$

where N is the number of items to be sorted. In the present example, it can be seen that $2^{10} = 1{,}024 > 1{,}000$; therefore, 10 passes is sufficient. At 18 sec per pass, this equals 180 sec, or 3 min. A 600-card-per-minute punched-card sorter would require over 8 min to sort these same 1,000 items (assuming a 5-digit key), while commercial general-purpose drum computers might require 15 to 20 min to perform the same sort.

The logic of the above equation is quite simple. In the first pass through the sorter, each ascending sequence will have at least two items. In the next pass, the strings will have four items at least. The sequences double in length with each pass, until the total number of items occurs in one string.

From the design viewpoint, there are other interesting details involved in these sorters. Among these are the need for an even number of passes; the need for counting items so that none are lost in the sorting process; methods for sorting items which exceed the length of the buffers; running tapes backwards on even-numbered passes. These same machines, properly designed, can also be used for file separation and merging. A comparison of the digit-by-digit sorting method with the merging-sort method would also be of interest. The reader can find information on such points in the references cited.

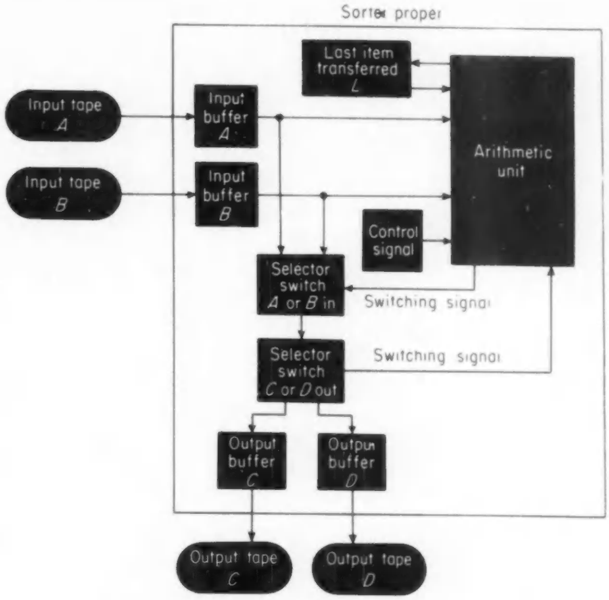

FIG. 5. Simplified block diagram of four-tape sorter.

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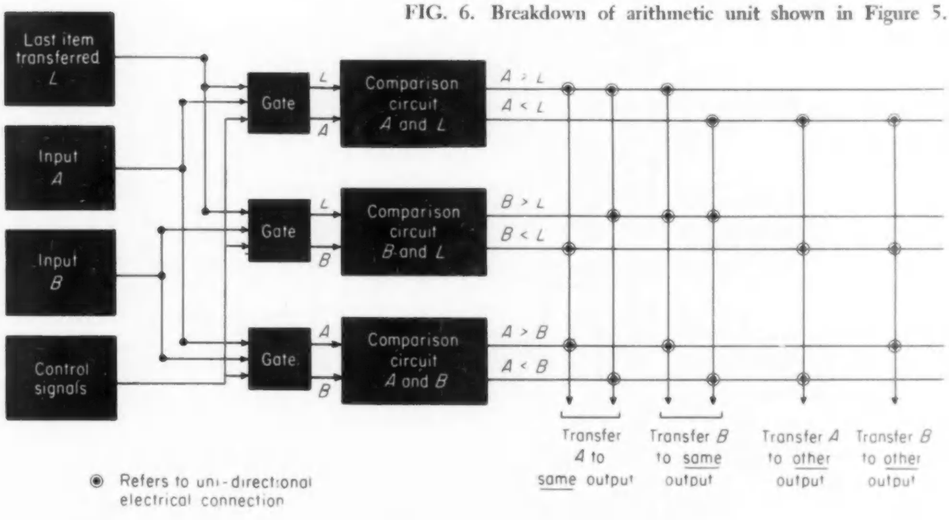
FIG. 6. Breakdown of arithmetic unit shown in Figure 5.

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Sampled-Data Systems

THE GIST: In systems where the controller is a digital device, the input is not a continuous function of time, but a sample value of the input time function taken at some discrete moment and operated on according to the instructions programmed into the controller. The signals are known intermittently, or at discrete moments usually assumed equally spaced in time[5], and are not defined at all in the open intervals between successive sampling instants. The error (or input signal) is measured, a correction applied, and then the system waits a while before the error is again determined. This delay increases the stability problem, so that special techniques are required to analyze and synthesize sampled-data systems.

Sampling techniques are used in radar equipment, data transmission links, machine tool controls, and digital control systems in general[23, 24, 36]. In some cases, one digital controller may be controlling several variables. Here, the input sampling systems may be scanned in sequence, and the controller time-shared between the variables. Sampling techniques are also used where high power gain and low drift are required, as with sensitive measuring instruments. Large amounts of power can easily be controlled by sampling techniques, for example by using relays.

Suppressed or nonsuppressed ac carrier servos are still other examples of sampled data systems. In all sampling systems, if the signal changes little in one period of the carrier wave, or in one sampling period, the equations reduce to those for an equivalent continuous servomechanism. However, as the carrier or sampling frequency decreases relative to the signal band, this approximation becomes less valid, and more comprehensive analytical techniques must be used.

Dr. Gimpel defines and illustrates new words, concepts, and devices peculiar to these systems, and discusses system properties and the more important methods of predicting system performance. Theory is turned into practice in the detailed treatment of a digital machine tool control system. One of the most useful portions of the article is the comprehensive bibliography correlated where possible with the body of the text.

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Digital systems using sampled-data techniques offer a number of distinct advantages which offset the more difficult computation required to predict sampled-data system performance, Table I. Since these systems do differ considerably from conventional continuous control systems, it is best to define some of the new words, concepts, and devices before proceeding with the techniques for analyzing and synthesizing sampled-data systems.

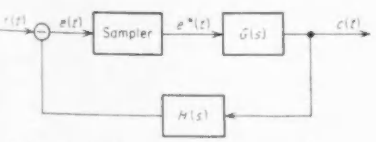


FIG. 1. A simple sampled-data system.

Table I—Why Use Digital Systems and Sampling Techniques?

- Error sampling devices can be made extremely sensitive in terms of power gain, with small drift at the expense of bandwidth. Relatively low-power-level signals can be readily amplified by a chopper and an ac amplifier, or by a relay.
- Sampled data in the form of digital numbers or coded signals can be transmitted with comparatively good fidelity over relatively poor communication circuits.
- Digital data can be readily stored, and subsequently reintroduced into the system without loss of fidelity. This allows elaborate command signal programs to be constructed and introduced with extremely high accuracy.
- New filter and compensation techniques based on coupling control systems with digital computers have been used with noteworthy results.
- Digital data can be operated on mathematically, without, to a large degree, concurrently introducing noise or errors.
- Digital sensing devices, particularly rotary and linear position sensors, are available that have an accuracy and overall resolution difficult to achieve with conventional analog techniques.

The Sampler. Figure 1 shows a sampled-data system. The command signal is $r(t)$ and the controlled variable $c(t)$, the transfer function of the forward path is indicated by $G(s)$ and that of the feedback path $H(s)$, where s is the Laplace transform variable. One new block, the "sampler" or "sampling device"[8,17], is shown operating directly on the error signal. In its simplest form the sampling device may be a switch, closed momentarily at equally spaced intervals of time. Also known as an impulse modulator, this switch converts each single frequency function of the input into a multiple frequency function, generally expressed in the form of an infinite series. The series consists of the input frequency and an infinite series of sidebands at $\pm\omega_i$, $\omega_r \pm \omega_i$, $2\omega_r \pm \omega_r$, and so on. Here ω_r is the sampling frequency and ω_i the modulated signal frequency. The amplitude of each sideband frequency is identical to that of the fundamental, while the phase is symmetrical about 0, ω_r, $2\omega_r$, and so on. These terms are defined in Figures 2 and 3. Note that T is defined as the sampling period.

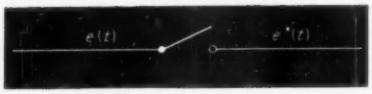


FIG. 2. Impulse modulator or sampler.

Figure 4B shows the effect of the sampler if the input signal has a spectral distribution as shown in Figure 4A. This distribution is repeated about zero, $\pm\omega_r$, $\pm 2\omega_r$, etc. Also note that if the upper cutoff frequency of the input signal is ω_c, and the sampled signal is passed through a low-pass filter with a cutoff frequency of $\omega_r/2$, the original signal would be recovered if $\omega_c \leqq \omega_r/2$. If the cutoff frequency of the original signal were larger than $\omega_r/2$, the spectral distribution from 0 to ω_c would overlap, in part, that from ω_r to $\omega_r - \omega_c$ and the low-pass filter would recover the original signal distorted by the overlapped portion of the first sideband. This can be expressed differently: if the highest input frequency is ω_c, then the sampling frequency must be at least $2\omega_c$ to make it possible to recover the undistorted input signal[6].

The relationship between the input to the sampler, $e(t)$, and its output, $e^*(t)$, is

$$e^*(t) = e(t)[\delta(0) + \delta(t - T) + \cdots + \delta(t - nT) + \cdots] \qquad (1)$$

It is assumed that $e(t) = 0$ for $t < 0$. In the above $\delta(t - nT)$ is a unit impulse at time $t = nT$, and the product $e(t)\delta(t - nT)$ has the value of $e(t)$ at time nT, or $e(nT)$, and is zero everywhere else. Equation 1 can therefore be written in the equivalent form

$$e^*(t) = \sum_{n=0}^{\infty} e(nT)\,\delta(t - nT) \qquad (2)$$

Taking the Laplace transform of Equation 2 gives the desired expression immediately:

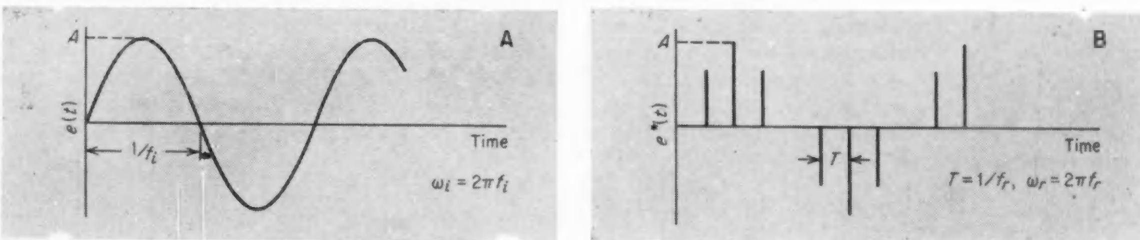
$$E^*(s) = \sum_{n=0}^{\infty} e(nT)e^{-snT} \qquad (3)$$

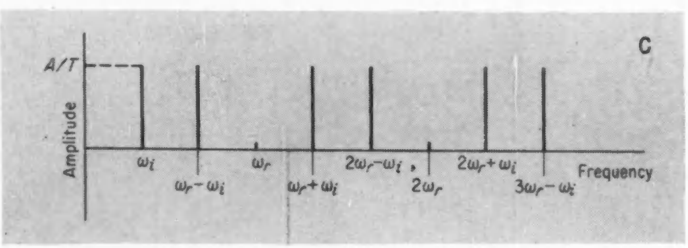
A completely equivalent form of Equation 3 is obtained by writing the Fourier series expansion for a train of impulses, substituting the series in Equation 1, and then transforming both sides. This gives

$$E^*(s) = \frac{1}{T}\sum_{n=-\infty}^{\infty} E(s + jn\omega_r) + \frac{e(0)}{2} \qquad (4)$$

Equations 3 and 4 serve as the basis for all sampled-data theory, in that beginning with these equations, the properties of these systems can all be derived. The last term of Equation 4, included to take care of discontinuities at $t = 0$, is often dropped[38].

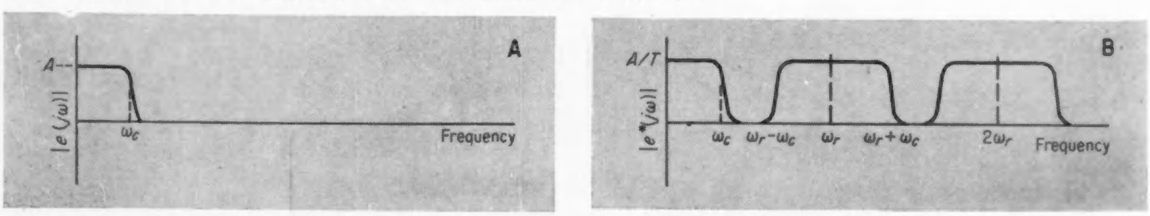
FIG. 3. THE EFFECT OF SAMPLING A SINGLE FREQUENCY COMPONENT.





A. The modulating signal.
B. The modulated signal.
C. The sampler output as a function of frequency.

FIG. 4. THE EFFECT OF SAMPLING ON SPECTRAL DISTRIBUTION.



A. The input signal spectrum.

B. The sampled signal spectrum.

The Clamp Filter. A second device often used in sampled-data systems is a clamp circuit or equivalently, a "box-car" filter[4]. The clamp generally follows the sampler, and holds a constant value equivalent to the impulse peak for a fixed duration up to T sec. Figure 5 shows the clamping action.

In terms of Laplace transforms, the transfer function of a clamp is

$$G_c(s) = \frac{1 - e^{-sT}}{s} \tag{5}$$

If written in terms of amplitude and phase versus frequency, Equation 5 becomes

$$|G_c(j\omega)| = \frac{2\pi}{\omega_r} \frac{\sin \pi\omega/\omega_r}{\pi\omega/\omega_r}; \tag{6}$$

$$\omega_r = 2\pi/T$$

$$\angle G_c(j\omega) = -\pi\omega/\omega_r \tag{7}$$

The function of the clamp is to convert the train of impulses to an almost continuous function of time. More complicated clamp circuits can be devised by generating functions whose initial value is the value of the sampled signal, but whose form during the sampling interval is variable. In other words, the clamp need not hold the value of the sampled signal at a constant value[16]. Most of the literature, however, assumes a constant value clamp, as is assumed here.

SYSTEM ANALYSIS AND SYNTHESIS

The problems normally encountered in the synthesis and analysis of conventional continuous control systems have their parallel in the sampled-data systems, with the additional complication of the sampler. As an example, the effect of the sampler, or of knowing one of the signals in the system only at discrete points in time, is that the output to a specified input can be known only at the same time points. There is, however, an artifice that permits calculating the output at intermediate points[28].

An important tool in the analysis of continuous systems is the Laplace transform theory. In most cases, the transfer function for a network can be represented by the ratio of two polynomials in s, that is, as an algebraic function. The effect of the sampler is to produce an equivalent transfer function involving the ratio of two polynomials in e^{sT}, or a transcendental function, Equation 2. And by replacing e^{sT} by some other symbol, say z, it is again possible to obtain an algebraic relationship similar to the familiar form. This is the essence of the z-transform theory proposed by Hurewicz[4] and expanded and unified by Ragazzini and Zadeh[25]. Most of the properties of sampled-data systems have been derived with the aid of this theory, and most of the techniques for analyzing these systems come directly from the z-transform method. Using the z-transform theory, the analysis of sampled-data systems closely parallels that of continuous systems.

In the discussion that follows, a continuous function of time is represented by $r(t)$, $c(t)$, etc. The sampled function of time is represented by starring the continuous function, i.e., by $r^*(t)$, $c^*(t)$, etc. Similarly, the Laplace transform corresponding to $r(t)$ is $R(s)$, and that corresponding to $r^*(t)$ is represented by $R^*(s)$, a transcendental function. If z replaces e^{sT} in $R(s)$, then a function of $R(1/T \ln z)$ or $R^*(z)$ corresponds to $R^*(s)$[25,30]. These relationships are summarized in Table II and correspond with the block diagram of Figure 1.

A summary of the important relationships in sampled-data systems is given below. For simplicity, most of the derivations of these formulas have been omitted.

Periodicity

There are two different but equivalent expressions relating the output of a sampler to its input. From Equations 3 and 4 these are

$$E^*(s) = \sum_{n=0}^{\infty} e(nT)e^{-snT} =$$

$$\frac{1}{T} \sum_{n=-\infty}^{\infty} E(s + jn\omega_r) \tag{8}$$

The output of the sampler, $E^*(s)$, is a periodic function of s with period ω_r. This can be seen by noting that the s in $E(s + jn\omega_r)$ can be replaced by $(s + jm\omega_r)$ without altering the expression. Figures 3 and 4 show this periodicity. If z replaces e^{sT} in Equation 8, then

$$E^*(s) = E^*\left(\frac{1}{T} \ln z\right) = \sum_{n=0}^{\infty} e(nT)z^{-n} \tag{9}$$

Again, by convention, this can be rewritten

$$E^*(z) = \sum_{n=0}^{\infty} e(nT)z^{-n} \tag{10}$$

Transfer function

One of the most convenient and useful concepts in the analysis of continuous systems is the transfer function relating the output of a filter to its input. For a continuous system, the composite transfer function for two noninteracting filters in tandem is simply the product of the two transfer functions. The same general relationship can be found for sampled-data systems, complicated by the

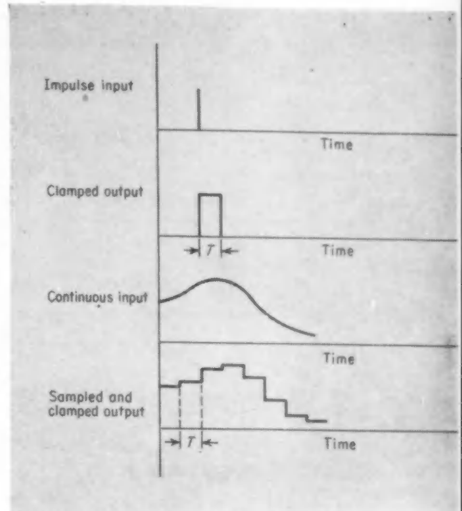


FIG. 5. The effect of a clamp filter.

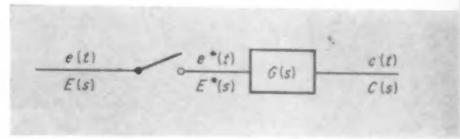


FIG. 6. Relationship between variables in a sampler-filter pair.

presence of the sampler. It can be shown that for Figure 6

$$C^*(z) = G^*(z)E^*(z) \tag{11}$$

The transfer functon $G^*(s)$ of a sampled-data system is given by

$$G^*(s) = \frac{1}{T} \sum_{n=-\infty}^{\infty} G(s + jn\omega_r) \tag{12}$$

If $G(s)$ is composed of the tandem combination of $G_1(s)$ and $G_2(s)$, then the starred transfer function of the pair is

$$G^*(s) = \frac{1}{T} \sum_{n=-\infty}^{\infty} G_1(s + jn\omega_r)G_2(s + jn\omega_r) \tag{13}$$

This is often abbreviated to

$$G^*(s) = G_1G_2{}^*(s) \tag{14}$$

The product of two transfer functions not separated by a sampler is not the product of their starred transforms but a new function defined by Equation 14. If the two are separated by a sampler, the transfer function of the pair becomes

$$G^*(s) = \left[\frac{1}{T} \sum_{n=-\infty}^{\infty} G_1(s + jn\omega_r)\right]$$

$$\times \left[\frac{1}{T} \sum_{n=-\infty}^{\infty} G_2(s + jn\omega_r)\right] \tag{15}$$

Table II—Summary of Symbols

	Command (input)	Controlled variable (output)	Error signal (to sampler)	Error signal (after sampler)	Filter
function of time	$r(t)$	$c(t)$	$e(t)$	$e^*(t)$	$g(t)$[1]
Laplace transform	$R(s)$	$C(s)$	$E(s)$	$E^*(s)$	$G(s)$
z-transform	$R(z)$	$C(z)$	$E(z)$	$E^*(z)$	$G^*(z)$

[1]Note $g(t)$ is the response of the network to a unit impulse input

Table III—Abbreviated Table of Laplace and Z-Transforms[1]

Time Function $f(t)$	Laplace Transform $F(s)$	z-Transform $F(z)$	Explanation
1. $\lim_{t \to \infty} f(t)$	$\lim_{s \to 0} sF(s)$	$\lim_{z \to 1} \frac{(z-1)}{z} F(z)$	Final value
2. $\lim_{t \to 0} f(t)$	$\lim_{s \to \infty} sF(s)$	$\lim_{z \to \infty} F(z)$	Initial value
3. $e^{-at}f(t)$	$F(s+a)$	$F(e^{aT}z)$	Complex translation
4. $f(t+a)$	$e^{as}F(s)$	$z^{a/T}F(z)$	Real translation
5. $f(t-T)$	$e^{-Ts}F(s)$	$F(z)/z$	Translation by T
6. $\delta(t)$	1	1	Unit impulse
7. $\delta(t-nT)$	e^{-snT}	$1/z^n$	Delayed impulse
8. $u(t)$ or 1	$\frac{1}{s}$	$\frac{z}{z-1}$	Unit step
9. t	$1/s^2$	$\frac{Tz}{(z-1)^2}$	Ramp
10. e^{-at}	$\frac{1}{s+a}$	$\frac{z}{z-e^{-aT}}$	Exponential
11. $1-e^{-at}$	$\frac{a}{s(s+a)}$	$\frac{z(1-e^{-aT})}{(z-1)(z-e^{-aT})}$	
12. $\sin at$	$\frac{a}{s^2+a^2}$	$\frac{z \sin aT}{z^2 - 2z\cos aT + 1}$	Sine function
13. $\cos at$	$\frac{s}{s^2+a^2}$	$\frac{z - \cos at}{z^2 - 2z\cos aT + 1}$	Cosine function
14. $i(t)$	$\frac{1}{1-e^{-Ts}}$	$\frac{z}{z-1}$	A train of impulses at the sampling instants
15. $a^{t/T} \sin bt$	$\frac{b}{(s - \frac{1}{T}\ln a)^2 + b^2}$	$\frac{za \sin bt}{z^2 - 2az\cos bT + a^2}$	Damped sine wave
16. $a^{t/T} \cos bt$	$\frac{s - \frac{1}{T}\ln a}{(s - \frac{1}{T}\ln a)^2 + b^2}$	$\frac{z(z - a\cos bT)}{z^2 - 2az\cos bT + a^2}$	Damped cosine wave

[1]This table was largely derived from Reference 7.

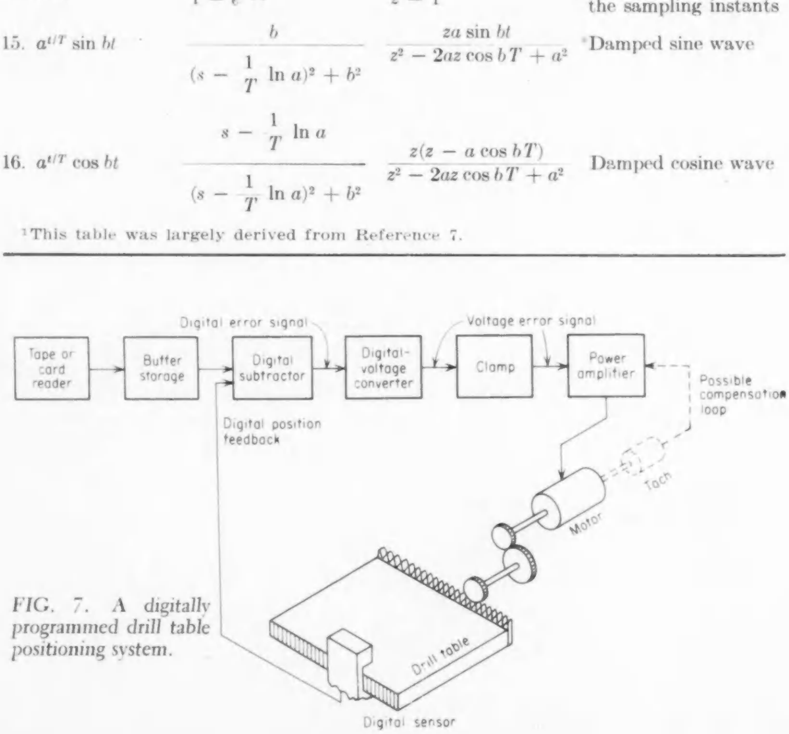


FIG. 7. A digitally programmed drill table positioning system.

which in abbreviated form becomes $G^*(s) = G_1^*(s)G_2^*(s)$.

Series expansion

Equation 12 relates the starred transfer function to $G(s)$, the transfer function for a continuous system. If ω_r is high relative to the passband of $G(j\omega)$, Equation 12 can be represented by the first terms of the series

$$G^*(j\omega) = \frac{1}{T}\Big\{G(j\omega) + G[j(\omega + \omega_r)] + G[j(\omega - \omega_r)] + G[j(\omega + 2\omega_r)] + G[j(\omega - 2\omega_r)] + \cdots\Big\} \quad (16)$$

This expansion is particularly valuable if $G\,[j(\omega + n\omega_r)]$ is out of the passband by some low value of n, say 2 or 3. If ω_r is low relative to the passband, then more terms must be included, complicating the calculations. If Equation 16 can be approximated by a few terms of the series, then the starred transform can be derived graphically by the addition of vectors. This is the basis for graphical solutions.

Calculating the starred transfer function

Another method for deriving the starred transfer function is to obtain a closed form for the summation of Equation 12. This can be done for many cases of interest, but becomes involved if $G(s)$ is not simple. Still another technique for obtaining $G^*(s)$ is by direct calculation or by the use of laboratory measurements based on the relationship of Equation 8. The first step is to compute the time response of a network to an impulse input. Given the time response, say $e(t)$, replace it by $e(nT)$ where $n = 0, 1, 2, \ldots$. Next substitute these values in

$$E^*(s) = e(0) + e(T)e^{-Ts} + e(2T)e^{-2Ts} + \cdots \quad (17)$$

Finally, close the series. This is often accomplished more readily than for Equation 16.

This can be demonstrated by a simple example. Assume

$$G(s) = \frac{K}{s+a} \quad (18)$$

The time response to an impulse is

$$g(t) = Ke^{-at} \quad (19)$$

Then

$$g(nT) = Ke^{-anT} \quad (20)$$

Substituting this in Equation 17 gives

$$G^*(s) = \sum_{n=0}^{\infty} Ke^{-anT}e^{-snT} \quad (21)$$

The closed form for this summation is

$$G^*(s) = \frac{K}{1 - e^{-aT}e^{-sT}} \tag{22}$$

or

$$G^*(z) = \frac{K}{1 - e^{-aT}z^{-1}}$$

A number of z-transforms derived in this manner are given in Table III.

Time response

Equation 17 also provides a convenient means for obtaining the time response of a network to a specified input. If the output of the network to the given input is $C^*(z)$, expanding the expression yields a series in z^{-n},

$$C^*(z) = b_0 + b_1z^{-1} + b_2z^{-2} + \cdots \tag{23}$$

The b_n can be identified with the $c(nT)$ of Equation 17, thus giving the time response of the network at $t = 0, T, 2T, \ldots$, or at discrete points in time.

The effect of sampler location

Sampler location has an important bearing on the resultant overall system transfer function. A summary of the overall transfer functions for some basic feedback systems is given in Table IV.

Use of Tables III and IV can be illustrated by an example. Consider configuration 4 of Table IV with $G(s) = Ka/(s + a)$ in tandem with a clamp, and let $H(s) = 1$. Now calculate the output corresponding to a step command. The transfer function from Table IV is

$$C^*(z) = \frac{G^*(z)R^*(z)}{1 + HG^*(z)} \tag{24}$$

The z-transform for a unit step is, from Table III number 8,

$$R^*(z) = \frac{1}{1 - z^{-1}} \tag{25}$$

Substituting in Equation 24 gives

$$C^*(z) = \frac{\dfrac{Ka}{1 - e^{-aT}z^{-1}}\left(\dfrac{1}{1 - z^{-1}}\right)}{1 + \left(\dfrac{Ka}{1 - e^{-aT}z^{-1}}\right)}$$

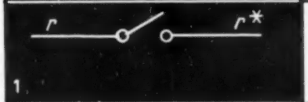
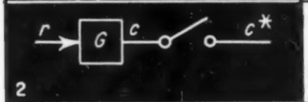
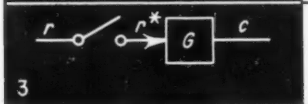
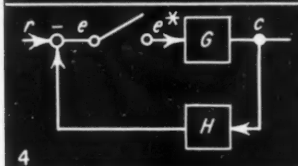
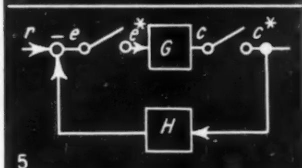
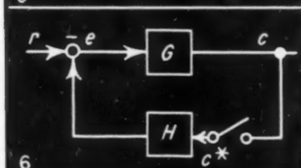
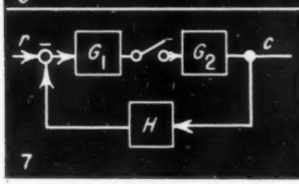
$$C^*(z) = \frac{Ka}{(1 - z^{-1})(1 + Ka - e^{-aT}z^{-1})} \tag{26}$$

The time function corresponding to Equation 26 can be obtained by two different methods. The first is to expand Equation 26 into partial fraction form and locate the respective inverse transforms of the separate terms from Table III. This proceeds as follows:

$$C^*(z) = \frac{Ka}{(1 + Ka - e^{-aT})(1 - z^{-1})} - \frac{Ka\, e^{-aT}}{(1 + Ka - e^{-aT})(1 + Ka - e^{-aT}z^{-1})}$$

TABLE IV

OUTPUT TRANSFORMS FOR BASIC SAMPLED-DATA SYSTEMS[1]

System	Laplace transform of output $C(s)$	z-transform of output $C(z)$
1 	$R^*(s)$	$R(z)$
2 	$GR^*(s)$	$GR(z)$
3 	$G(s)R^*(s)$	$G(z)R(z)$
4 	$\dfrac{G(s)R^*(s)}{1 + HG^*(s)}$	$\dfrac{G(z)R(z)}{1 + HG(z)}$
5 	$\dfrac{G^*(s)R^*(s)}{1 + H^*(s)G^*(s)}$	$\dfrac{G(z)R(z)}{1 + H(z)G(z)}$
6 	$G(s)\left[R(s) - \dfrac{H(s)RG^*(s)}{1 + HG^*(s)}\right]$	$\dfrac{RG(z)}{1 + HG(z)}$
7 	$\dfrac{G_2(s)RG_1^*(s)}{1 + HG_1G_2^*(s)}$	$\dfrac{G_2(z)RG_1(z)}{1 + HG_1G_2(z)}$

[1]This table is taken directly from Reference 25

$$c(t) = \frac{Ka}{(1 + Ka - e^{-aT})} \times \left\{1 - \left(\frac{e^{-aT}}{1 + Ka}\right)^{\frac{t+T}{T}}\right\}$$

$$c(nT) = \frac{Ka}{(1 + Ka - e^{-aT})} \times \left\{1 - \left(\frac{e^{-aT}}{1 + Ka}\right)^{n+1}\right\} \tag{27}$$

This function might also be obtained by expanding Equation 26 into an infinite series

$$C^*(z) = \frac{Kd}{1 + Ka - e^{-aT}}\left\{[1 + z^{-1} + z^{-2} + \cdots] - \frac{e^{-aT}}{1 + Ka}\left[1 + \left(\frac{e^{-aT}}{1 + Ka}\right)z^{-1} + \left(\frac{e^{-aT}}{1 + Ka}\right)^2 z^{-2} + \cdots\right]\right\}$$

$$C^*(z) = \frac{Ka}{1 + Ka - e^{-aT}}\left\{1 - \frac{e^{-aT}}{1 + Ka} + \left[1 - \left(\frac{e^{-aT}}{1 + Ka}\right)^2\right]z^{-2} + \cdots\right\}$$

$$c(nT) = \frac{Ka}{1 + Ka - e^{-aT}} \times \left\{1 - \left(\frac{e^{-aT}}{1 + Ka}\right)^{n+1}\right\} \tag{28}$$

Stability of sampled-data systems

When sampled-data systems are analyzed by using the counterpart of the transfer function of a continuous system, the usual techniques for determining stability still apply: the Ny-

FIGS. 8-11. AMPLITUDE & PHASE VS. FREQUENCY FOR VARIOUS A VALUES

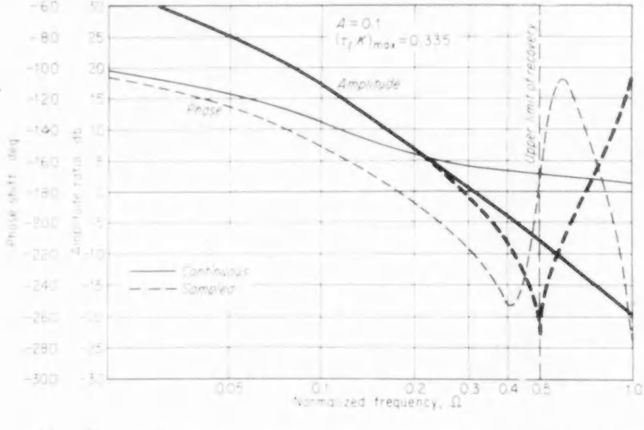


FIG. 8.
A = 0.1

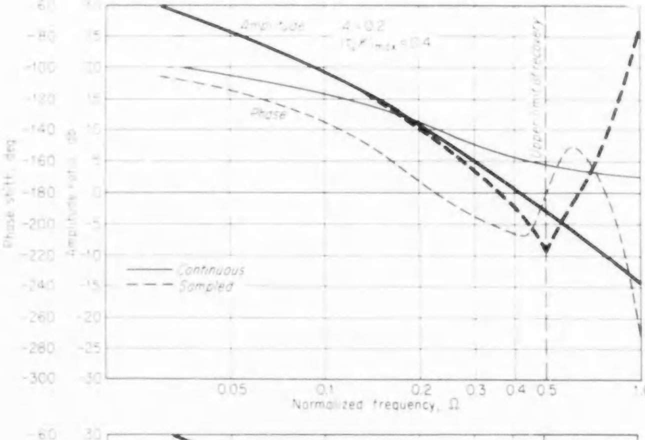


FIG. 9.
A = 0.2

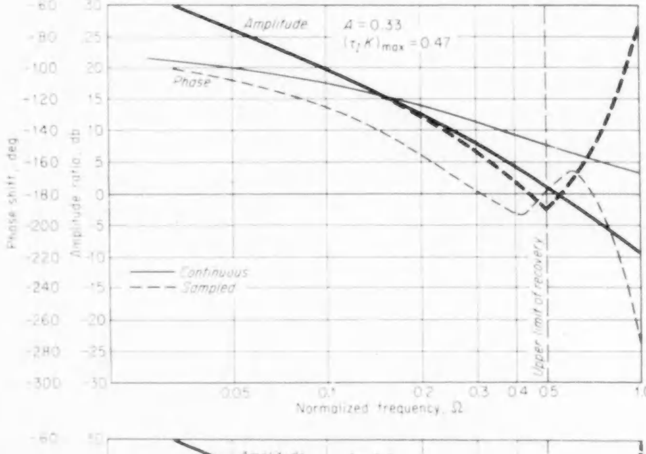


FIG. 10
A = 0.33

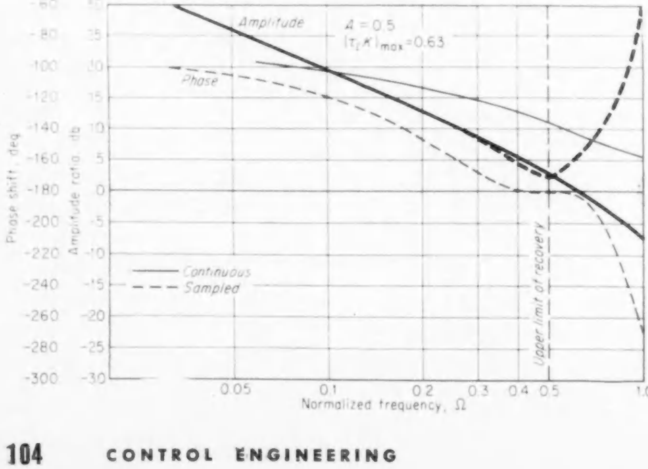


FIG. 11
A = 0.5

quist plots, the amplitude and phase versus frequency representation, etc., can be used directly.

To determine the stability of a given continuous system directly from the transfer function relating its input to output, the overall transfer is examined for its pole locations. If any of the poles lie in the right-half s-plane, the system is said to be unstable. If any of the poles lie on the imaginary axis, the system is said to be marginally stable. If all the poles lie in the left-half plane, the system is stable, the degree of this stability depending on the relative closeness of the pole locations to the imaginary axis. The effect of the substitution $z = e^{sT}$ is to transform the left-half plane to the interior of a unit circle. The criteria for stability for a sampled-data system is therefore that the poles of the overall z transform lie entirely within the unit circle. The system will be marginally stable or unstable if any poles are on or outside the unit circle.

SAMPLED-DATA CONTROL OF A MACHINE-TOOL TABLE

To see how sampled-data techniques work in a typical application, take the development of a system that will program and control table motion so that a number of specified holes can be drilled in a workpiece. This is a discrete positioning system—only the hole locations, not the tool path between holes, are important. Assume the positioning resolution and linearity requirements in one dimension of motion to be 0.5 mils over a range of 25 in., or equivalently, a resolution and linearity of 1:50,000 over the full range. The requirements on precision, plus the complex programming necessary for drilling multiple holes, severely strain the limits of conventional analog techniques.

Consider the digital system shown in Figure 7. The input can be from a deck of punched cards, a punched tape, or some other digital storage device. It is assumed that the programmer enters a digital number corresponding to a new hole position immediately after the last hole has been located, giving an input which is, in effect, a series of step commands available on a continuous basis from the buffer register. The primary position feedback could be from a shaft-position to digital sensor connected at a convenient point in the gear train, or could consist of one of many linear position-measuring devices attached to the machine table. For purposes of this problem, assume that a digital number corresponding to table position is continuously available, with one count corresponding to 0.5 mils. In addition, assume that

the digital subtractor is relatively fast, so that a number proportional to the error signal is available continuously.

The digital error is converted to a proportional voltage in the decoder $1/T$ times per second, and this voltage is held constant in the clamp circuit for T sec. Thus the clamp output is a continuous (except for step discontinuities) voltage proportional to the difference between programmed and desired table position. Note that unless auxiliary logic circuits are used, the decoder must function over the complete decoding range, i.e., it must resolve to 1:50,000, since it is possible to get an error signal corresponding to the maximum range or the number 50,000. Assume, however, that a suitable converter is available. The voltage output of the clamp circuit is amplified in terms of power level to drive a shunt-field-controlled dc motor. In turn, the motor drives the table through reduction gearing and a rack and pinion.

It is interesting to note that no other amplifier except the one required for the power level change to the motor field is used in the servomechanism. The digital-voltage converter serves as a drift-free amplifier, in which the gain can be varied by changing the voltage output corresponding to a given error count.

The object of this problem is to point out the effect of the decoding rate on the stability of the uncompensated servo. Note that some conventional compensation can be introduced by connecting an analog tachometer to the motor and summing at the clamp output.

The transfer function of the power amplifier, motor, and gear train is

$$K_mG_m(s) = \frac{X(s)}{E(s)} = \frac{K/\tau_l}{s\,(s+1/\tau_l)} \tag{29}$$

where x is the table position, e the error signal, and τ_l the load and motor time constant or the ratio of load inertia to friction. K is a gain constant relating bed velocity to a unit error signal, i.e., the velocity constant.

A comparison of Figure 7 to Figure 1 shows that for purposes of analysis they are essentially identical. Thus the transfer of the forward path is

$$KG(s) = K_mG_m(s)G_c(s)$$

$$= \frac{K/\tau_l}{s(s+1/\tau_l)}\,\frac{(1-e^{-sT})}{s} \tag{30}$$

It can be shown that the z-transform of the transfer function of the tandem combination of sampler, clamp, and motor is

$$KG^*(s) = K\tau_l e^{-sT}\left[\frac{T/\tau_l}{1-e^{-sT}} - \frac{1-e^{-T/\tau_l}}{1-e^{T/\tau_l}e^{-sT}}\right]$$

Substituting $j\omega$ for s and simplifying gives

$$KG^*(j\omega) = K\tau_l e^{-j\omega T/2}\left[\frac{T/\tau_l}{2j\sin\omega T/2} - \frac{\sinh T/2}{\sinh(1/\tau_l+j\omega)T/2}\right] \tag{31}$$

In turn, this equation can be rewritten

$$KG^*(j\omega) = \frac{K\tau_l\csc^2\omega T/2[1+D+B]}{MN} \tag{32}$$

where $D = (T/2\tau_l)\coth T/2\tau_l$
$B = j(T/2\tau_l)\cot\omega T/2$
$M = (1+j\cot\omega T/2)$
$N = (\coth T/2\tau_l + j\cot\omega T/2)$

The properties of this equation are easier to see if the following substitutions are made[27]:

$$fT = \Omega \quad \text{or} \quad \omega T/2 = \pi\Omega \tag{33}$$
$$T/2\tau_l = \pi A$$

Thus,

$$KG^*\left(j\,\frac{2\pi\Omega}{T}\right) = \frac{K\tau_l\csc^2\pi\Omega(1+F+Q)}{UV} \tag{34}$$

where $F = \pi A\coth\pi A$
$Q = j\pi A\cot\pi\Omega$
$U = (1+j\cot\pi\Omega)$
$V = (\coth\pi A + j\cot\pi\Omega)$

Since the feedback constant is unity, the denominator of the system transfer function connecting the bed position to the digital command is given by configuration 4 of Table IV.

$$1 + KG^*(j\omega)$$

The amplitude and phase-versus-frequency plots are given in Figures 8-11 for the cases: A = 0.1, 0.2, 0.33, and 0.5. These correspond to a ratio of decoding frequency to upper cutoff frequency, $1/\tau_l$ of 10:1, 5:1, 3:1, and 2:1, respectively.

The figures show that the curves are symmetrical about $\Omega = 0.5$, where $\Omega = 1.0$ corresponds to the sampling frequency. Since, as discussed earlier, there must be at least two samples per cycle of the highest intelligence frequency in order to recover the original intelligence, $\Omega = 0.5$ might be termed the upper limit of recovery.

The transfer function of the equivalent continuous servomechanism, or the low frequency asymptotic form of Equation 34, is

$$KG\left(j\,\frac{2\pi\Omega}{T}\right) = \frac{A(KT)}{j2\pi\Omega(A+j\Omega)}$$

Note that the continuous servo is always stable—there are no poles of the overall transfer function in the right half s-plane or on the imaginary axis for positive values of the gain constant. The question of absolute stability does not, therefore, enter into determination of the gain constant adjustment. It is decided, rather, by a specification of transient or steady-state performance, or possibly by a given phase margin. If the maximum gain is determined by an allowable phase margin, say 30 deg, then the maximum gain increases with increasing A for a fixed value of T. For example, for a phase margin of 30 deg, the maximum value of τ_lK is, from the curves, 0.13, 0.17, 0.21, and 0.25, for the cases A = 0.1, 0.2, 0.33, and 0.5, respectively.

The effect of sampling is to increase phase shift and thus decrease stability, as compared to the corresponding continuous case. For marginal stability the gain constant $(\tau_l K)_{max}$ varies as follows: 0.33, 0.40, 0.47, and 0.63, corresponding to A = 0.1, 0.2, 0.33, and 0.5. Thus the gain constant increases, but not as much as would be expected from the continuous case.

The design problem might also be considered from a reverse point of view, where the time constant is fixed and the sampling frequency varied according to the ratio 10:1, 5:1, 3:1, and 2:1. Assume that $T = 1$ and $1/\tau_l = 0.628$; then $(\tau_l K)_{max}$ is 0.33. For the same τ_l, lowering the sampling frequency by a factor of 2, or equivalently, raising T to 2.0, decreases the gain constant to 0.197, a reduction of approximately 40 percent. Lowering the sampling frequency further to $T = 3.0$ reduces the gain constant to 0.141; lowering it still further, to $T = 5.0$, gives a minimum of 0.124. Thus, there is a significant loss in system performance when the ratio of sampling frequency to upper cutoff is lowered from 10:1 to 5:1, where this loss is measured in terms of steady-state velocity error. The conclusion is that it is desirable to have a ratio as large as possible consistent with the feasibility of constructing a suitable decoder, with the positioning requirements, and with possible economic considerations. A sampling ratio of even 10:1 has a pronounced effect on system performance.

A FINAL WORD

To attempt to condense and summarize the theory of sampled-data systems in a simple and understandable form is difficult. The technique outlined here is but one of many[3, 14, 18], all making use of the z-transforms. To effectively use the z-transforms requires a good working knowledge of the Laplace transforms; however, one variation of this method is almost purely graphical, and through it rather extensive analyses can be performed.

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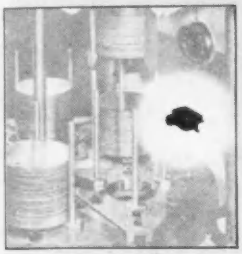
DONALD J. GIMPEL

Don Gimpel has been on top of most of the major developments in analog and digital computation since 1950, when he left Cal Tech with an MS in electrical engineering to work in the Aerial Measurements Laboratory of Northwestern University. The MS degree followed a BS in EE from Illinois Tech in 1949 and preceded a PhD from Northwestern in 1953. At the Aerial Measurements Lab, and at Armour Research Foundation, where he served as an engineer until last year, Gimpel undertook large-scale simulation studies, servomechanism analyses, and the design of computer components. He is now at Panellit, Inc., in charge of electronics research and development.

Switches have uses unlimited

Switches put "THINK" into this press transfer feed

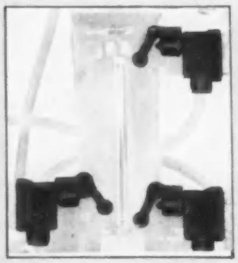
Here is a typical example of how a manufacturer improved his product. With MICRO SWITCH Precision Switches designed into the press, blanks are loaded and fed automatically, dangerous manual feeding is eliminated, mistakes are "erased" without interrupting production. This product improvement was due in no small measure to the help of MICRO SWITCH application engineers.



For more information for your design engineers, write for Catalog 83.

◀ When a stack of blanks is nearly depleted, the descending elevator trips this switch which starts a motor and turns the six-station turret to the next full station for blanks.

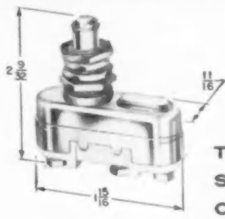
Plunger which picks up the blanks is controlled by switches shown. Upper switch stops the press if the blanks do not reach level of gripping fingers. Switch at left brings new stack of blanks into position. If stack doesn't come into position, the third switch stops press. ▶



◀ When two blanks stick together and feed into the press they trip this switch which actuates a solenoid and opens a trap door in the press bed. The blanks fall through, the press goes on uninterrupted.

SWITCH "REMEMBERS" CIRCUIT WHICH WAS LAST ACTUATED

This is the first of a new series of "electrical memory" toggle switches. The switch indicates through a pilot light or buzzer which circuit was last actuated. The assembly uses one pole of its four-pole circuitry to indicate which circuit was last operated. Use of this switch simplifies basic circuit designs of radar units, computers, aircraft control panels and other similar devices. Seal prevents entrance of liquids and dust. Basic switches are Underwriters' Listed at 5 amperes 125, 250 volts a-c, d-c rating at 28 volts-3 amperes at sea level, 2.5 amperes at 50,000 feet (inductive); 4 amperes at sea level and 50,000 feet (resistive); maximum inrush, 15 amperes.

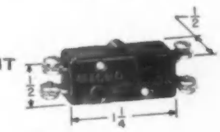


THIS SWITCH OPERATES RELIABLY AT TEMPERATURES FROM −50° TO +1000° F

Use of laboratory-tested, heat-resistant materials makes this switch an extremely dependable component for use in applications where high temperatures are present. It will operate satisfactorily in a temperature range of −50° to 1000°F. Contact arrangements are single-pole double-throw. Switch is available in panel-mount design (shown) or with pin- or roller-plunger actuators.

(Send for Catalog 77)

A TWO-CIRCUIT SWITCH WITH ACCURATE REPEATABILITY



This switch uses a snap-action spring to provide quick make and break of both contacts in each double-break circuit. It is Underwriters' Listed for 10 amperes 125 or 250 volts a-c; ½ H.P. 125 volts a-c; 10 amperes 30 volts d-c.

(Send for Catalog 62)

TWO SWITCHES OPERATED BY A SINGLE LEVER ACTUATOR

This is an assembly of two single-pole double-throw switches. It provides for switching of two isolated circuits at the same time. The basic units are listed by Underwriters' Laboratories at 15 amperes 125, 250 or 460 volts a-c; ½ ampere 125 volts d-c; and ¼ ampere 250 volts d-c.

(Send for Data Sheet 100)

MICRO SWITCH, a Division of Honeywell, pioneered the manufacture and development of precision snap-action switches.

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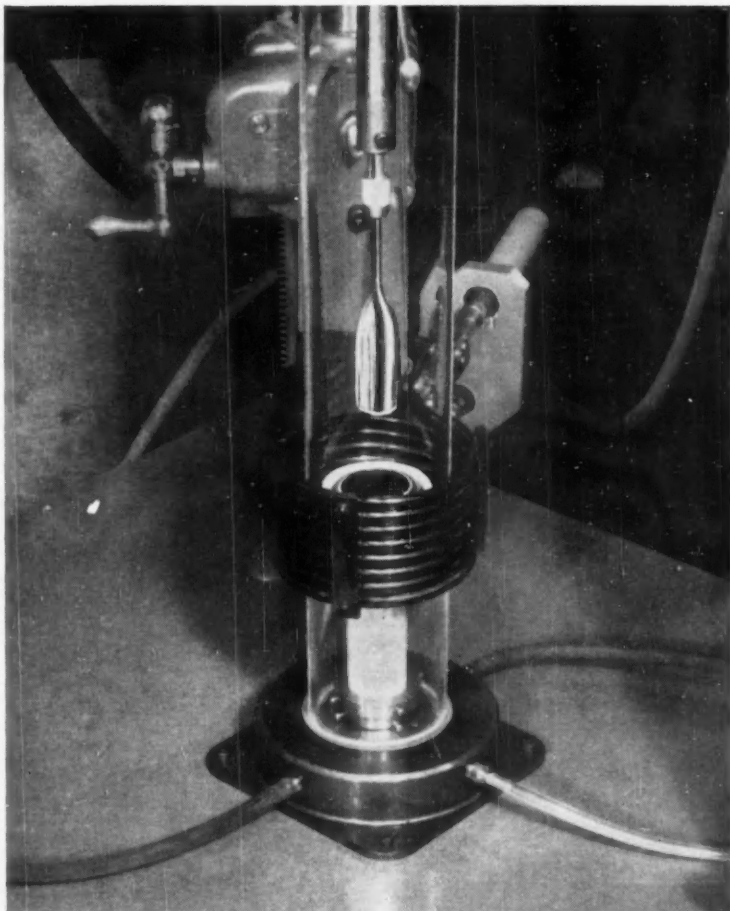
For closer temperature control in crystal growing...

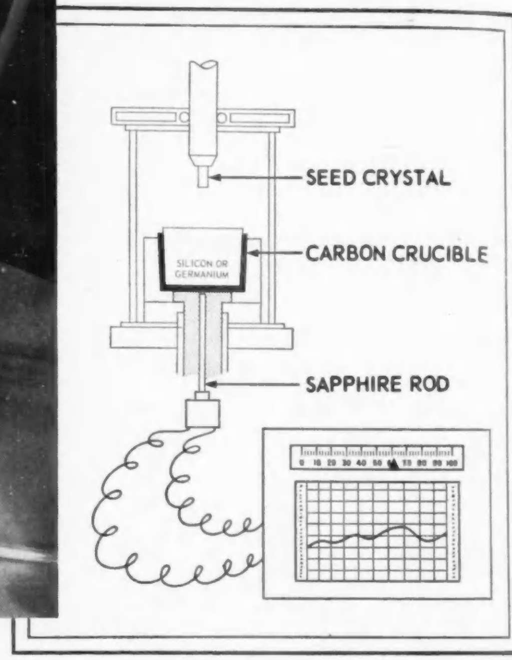


A typical crystal-growing installation is shown here. The sapphire light pipe is focused on the base of the crucible, and projects below the table surface. (See detail at right.)

Linde Trade-Mark

SAPPHIRE

Light Pipes



Volume production of germanium and silicon crystals used in transistors and diodes has spurred important developments in temperature measurement and control. In one new temperature measuring device a rod of LINDE synthetic sapphire is used as a light pipe. It has a refractive index of 1.77, furnishes reliable measurements at temperatures as high as 1850 degrees C., and allows temperature to be controlled to great accuracy.

LINDE synthetic sapphire—a single crystal of aluminum oxide—transmits a high percentage of radiation in important ultra-violet and infra-red regions. It has high mechanical strength, resists corrosion and abrasion, and retains its properties at high temperatures.

These and other attractive properties make sapphire ideal for other optical systems that require resistance to abrasion and corrosion as well as good transmission properties. It is also used for critical instrument parts that must resist extreme wear.

LINDE synthetic sapphire is available in the form of windows, rods, tubes, balls, and special shapes. If you would like more information on this product, please write, giving details of the proposed applications.

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Testing Hardness Automatically

Production line work demands a hardness tester that will automatically classify work-pieces as hard, soft, or satisfactory. The sequential nature of the manual operations, and the availability of dial indicator reading, led to development of a relatively simple sequential test procedure, with intervening timers properly timing the operations, and photoelectric reading of the dial indicator doing the classifying.

EUGENE RAVE
Wilson Mechanical Instrument Div., American Chain & Cable Co., Inc.

An understanding of how the automatic hardness tester works requires a knowledge of Rockwell hardness values and how they are obtained using manually operated equipment. There is no absolute measure of hardness, only relative hardness values. These values are derived by measuring the amount that a probe penetrates the material under test when subjected to a specified load. To make sure that there is a well-defined point from which to start measuring the penetration of the test load, a minor load is applied first to indent the test piece. This is the zero point. Then the test or major load is applied and released. The relative hardness is proportional to the change in penetration under the minor load, before and after the major load is applied.

In a manually operated machine, the test piece is inserted and the anvil raised until the full minor load is applied. Then the precision dial indicator is adjusted to zero and the major load applied. The dial-indicator reading with the major load removed (but with the minor load still applied) is a measure of the relative hardness of the test piece. For example, for the Rockwell C scale, a sphero-conical diamond penetrator is used with a minor load of 10 kg and a major load of 150 kg. The increment of penetration for each point of hardness is minus 0.00008 in.

The automatic machine

The control system divides naturally into two parts: the sequential and timing equipment required to operate the tester automatically, and the gage reading equipment for automatic classification of tested parts. If desired, the machine can be run automatically and the gage read by the operator.

Since the system circuit diagram is complex, no attempt will be made to cover it in detail. All operations can be clearly understood by referring to the simple schematic of Figure 1. Energizing the anvil motor and deenergizing the magnetic brakes start the cycle. As soon as the anvil rises far enough to touch the penetrator, and the minor-load spring starts to compress, the minor-load switch closes, starting the zero-set timer (period 0-0.5 sec). When this timer times out, the motor is deenergized and its brakes are energized. (The zero-set timer is included so that variations in the coast of the motor and anvil mechanism once the brake is applied can be compensated for by changing the time the motor runs while applying the minor load.) At this point in the cycle, the minor load is applied and the dial indicator is at zero. The cycle can continue without interruption, or can be delayed by 0-0.5 sec, which will hold the zero momentarily so that the zero-set timer can be accurately adjusted.

When the zero-set or zero-read timer times out (depending on whether the latter is used) the major-load solenoid is energized, causing the major load to be applied at a rate determined by the dashpot setting. The major-load limit switch is actuated when the load is fully applied, and the major-load motor removes the load. The major-load-off switch (cam actuated from major-load motor) closes when the major load is completely off, starting the read timer (period 0-0.5 sec). This is only used if the gage is read by the operator. At the completion of the read period, the down-drive timer (period 0-12 sec) starts, and the anvil motor is energized and its brakes deenergized. This timer determines the downward travel of the anvil. If simple pieces are being tested the down-drive distance can be small, but if test pieces are complex,

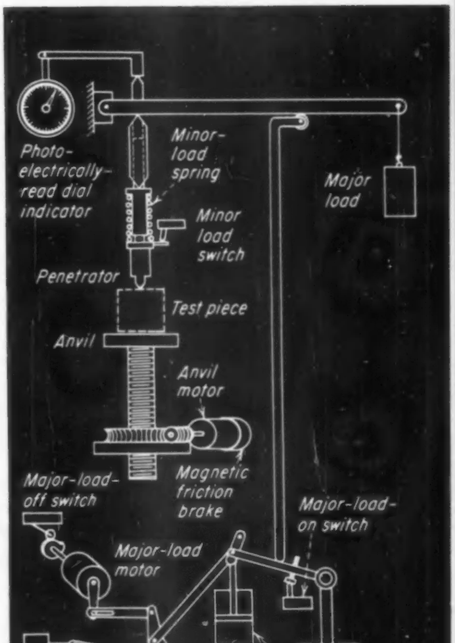


FIG. 1. Schematic of hardness tester.


When you need
Reliable Control
of Movement

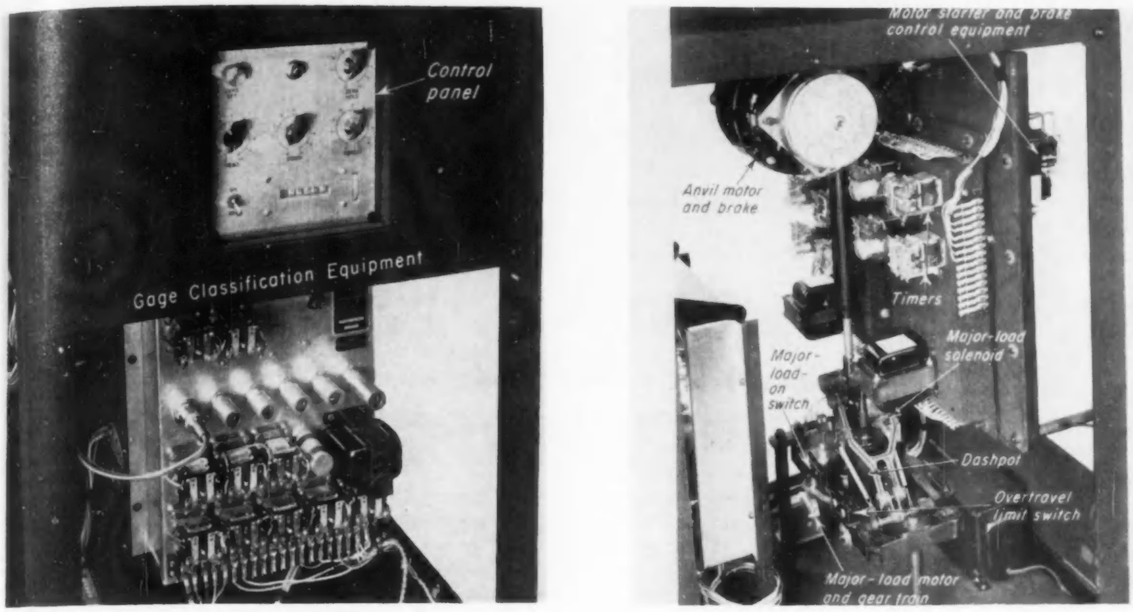


FIG. 2. The control equipment on the machine.

requiring maneuvering room, further travel is necessary. Of course, the shortest down-travel is used consistent with ease of loading and unloading the machine, since this reduces cycle time. When the down-drive timer times out, the repeat timer (period 0-12 sec) is started. At the end of this interval the cycle repeats.

The overtravel limit switch at the bottom of Figure 1 takes care of testing a piece that is so soft that the gage makes an extra turn and stops at the same reading as it would for a hard piece. Indicating lights notify the operator of this condition.

Figure 2 shows portions of the control equipment for this system.

A typical timing circuit

Since all the timers are similar except for different circuit parameters for various timing periods, they can all be represented by Figure 3. This is the circuit for the zero-set timer. The variable time delay is obtained by adjusting the phase shift between the grid and plate voltages of a thyratron. The curves show that changing the phase shift by changing the setting of the time-adjustment potentiometer causes the thyratron to fire at different times in the cycle. The smaller the phase shift, the greater the average voltage across the tube. During the time the tube is firing, the capacitor in parallel with the relay coil charges to a value dependent on the firing point. During the off portion of the cycle, some of the capacitor's charge drains off through the high-resistance relay coil (dc so that it does not respond to ac peak voltages), but the drain is small enough so that the capacitor is still charged when the tube fires again. As a result, the capacitor voltage increases with each succeeding cycle. After the required number of cycles, the voltage across the capacitor is sufficient to energize the relay and the unit times out. Increasing the phase shift delays the tube's firing point and increases the number of cycles required to build up capacitor voltage sufficiently to cause the relay to pull in. Decreasing the phase shift has the opposite effect. The timing period starts when the plate circuit is completed by closing the timer-start switch. On the hardness tester, this timer-start device is usually a relay or limit switch.

Automatic classification

Figure 4 shows the dial indicator,

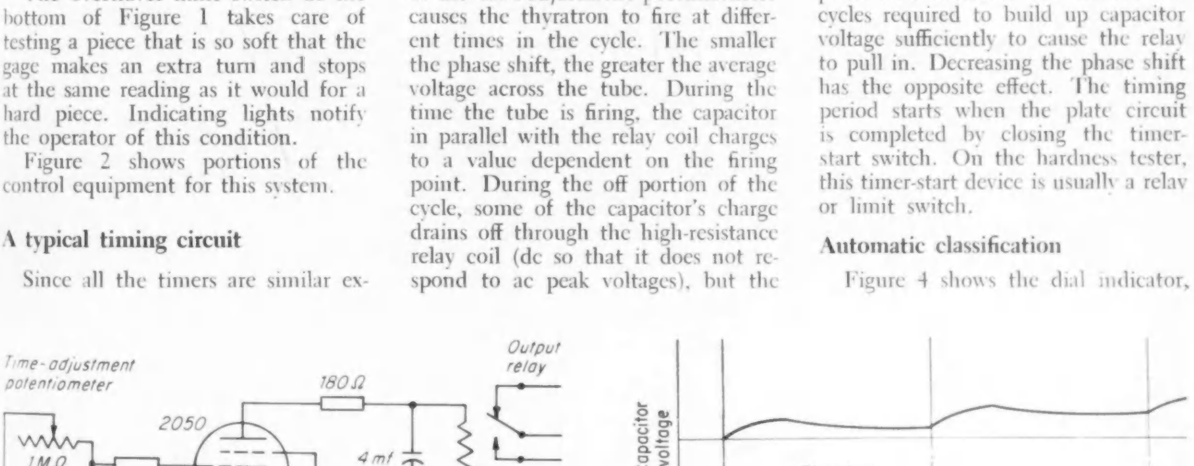
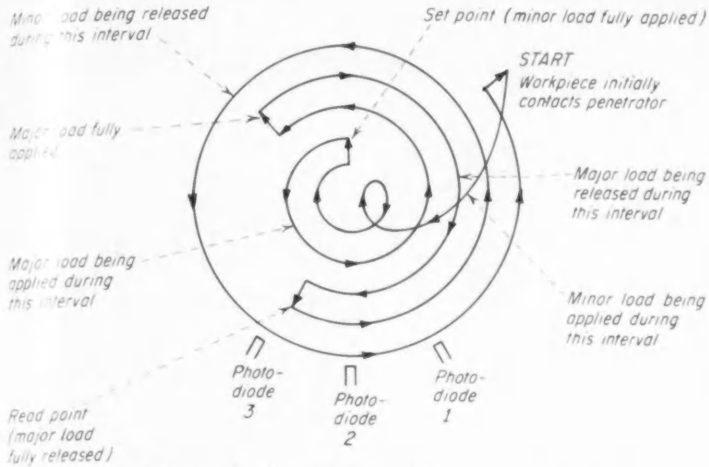


FIG. 3. A typical timing circuit and the capacitor charging curves.



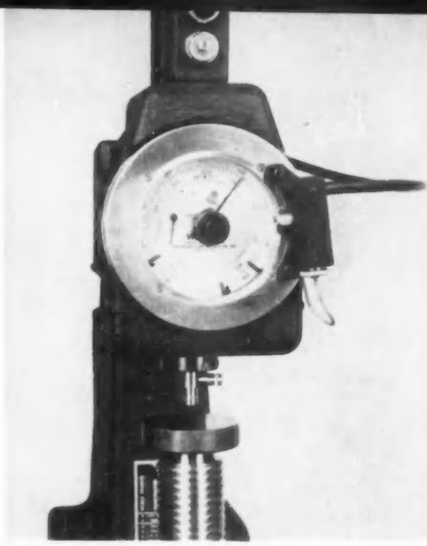


FIG. 4. The dial indicator and its operating cycle.

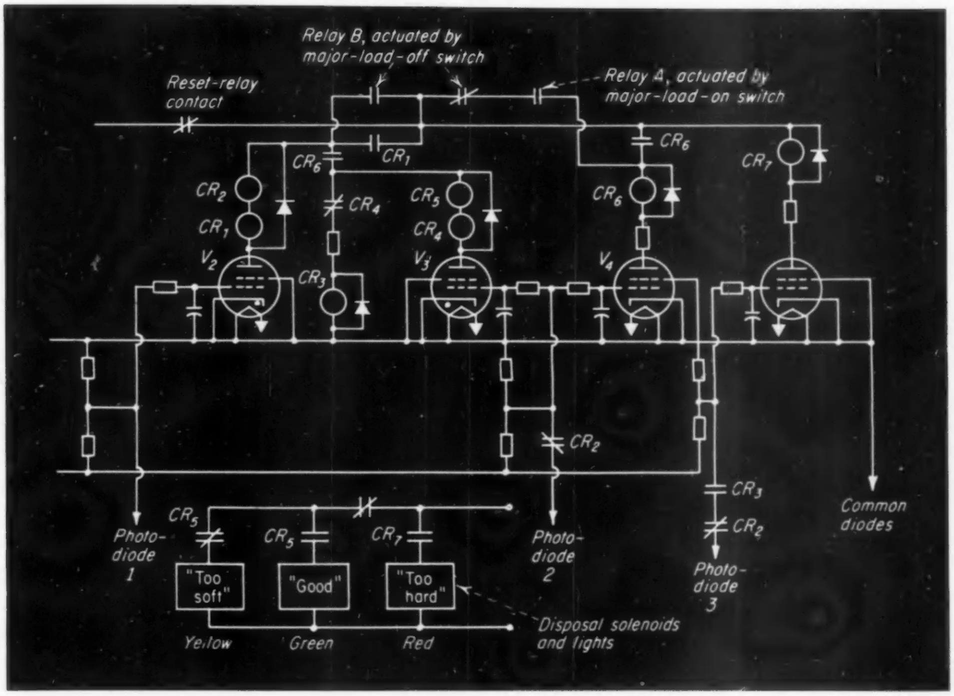


FIG. 5. The gage classification circuit.

the classification photodiodes, and the gage movement during a cycle. The positions of photodiodes 1, 2, and 3 indicate hardness classification zones. The diodes are energized by the stationary light source reflecting first onto a stationary 45-deg mirror at the hub of the indicator, and then onto a 45-deg mirror on the dial needle.

Figure 5 shows a simplified version of the gage system. **At the beginning of the cycle, the reset relay is pulsed to clear the last cycle conditions by breaking the plate circuit to all the** thyratrons. After the cycle of Figure 4, movement of the reflected light source past the photodiodes has no effect until the major-load-on switch closes. Then on the next clockwise trip past the photodiodes (major load being released), nothing happens at diode 1 because relay *B* has not been energized. At diode 2, thyratrons V_3 and V_4 fire, but only CR_6 pulls in, again because of relay *B*. This closes the normally open CR_6 contacts. If the diode 3 is passed (and relay *B* closes when the major-load-off switch is actuated), relay CR_7 pulls in because CR_6 is energized through the relay *B* contacts and CR_2 is not energized. The "too hard" disposal solenoid is energized and the red lamp lights. If the gage stopped between diodes 2 and 3, then relays CR_4 and CR_5 pull in (with relay *B* energized), energizing the "good" disposal solenoid and lighting the green lamp. If the gage pointer does not reach diode 2, then CR_1 and CR_2 are energized, and the "too soft" disposal solenoid and the yellow lamp are energized.

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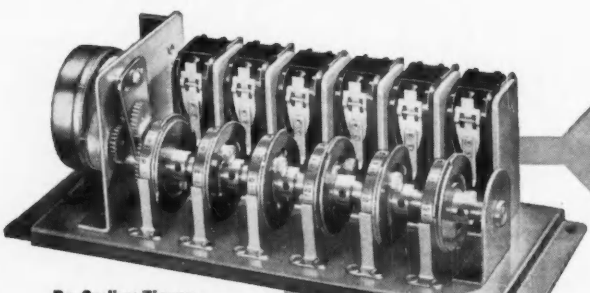

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Batch Process Sequenced by Rates of Change

Petroleum refining processes are usually continuous; however, there are still many cyclic operations essential to the industry in which the material in process must be handled batchwise. The processing time is not always sufficiently repeatable, however, for timer control. In such cases, rates of change of certain process variables can sometimes be used to indicate the state of the reaction and sequence the process.

H. B. BREEDLOVE
Esso Standard Oil Co.

The propane dewaxing plant at Esso's Baton Rouge refinery separates wax from lube oil stocks. In this process, propane is blended with lube oil, the mixture is chilled batchwise by flashing the propane, and the wax and oil are separated by continuous rotary filters. The operation is sequenced automatically by the rates of change of temperatures and pressures.

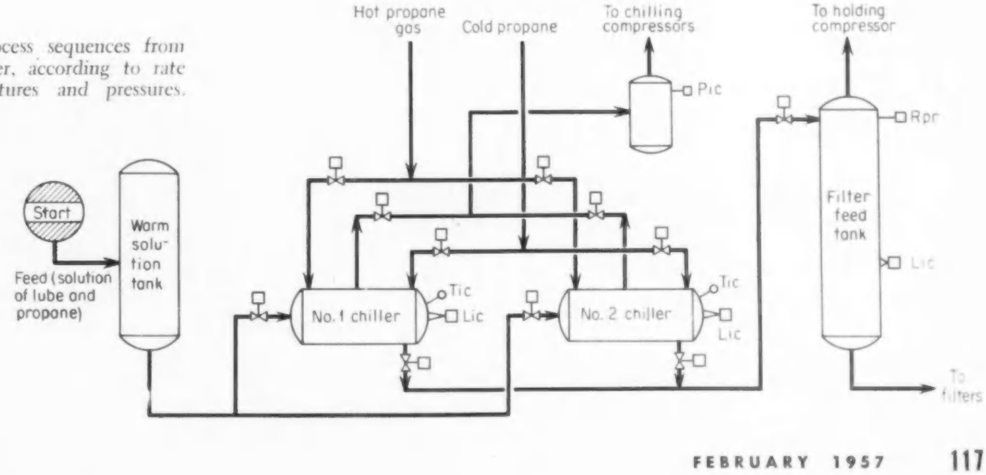
Careful control of the chilling cycle is important in maintaining maximum filtering capacity. Since the sequence controller was placed in operation, uniformity of the operation has improved and throughput increased.

Controlled system

The process equipment for the chilling operation is shown in Figure 1. It consists of a warm solution tank, two chillers, and a filter feed tank. Feed stock is mixed with propane in the warm solution tank and fed alternately to one of the two chilling drums. The chilling is done by filling a drum to the desired level, flashing the propane by venting to the gas compressors, and maintaining the desired solution composition by adding cold propane. When the solution has reached the desired temperature, the chiller is pressured with propane gas and the cold solution forced into the filter feed tank. The two chillers are alternately filled, chilled, discharged, warmed up, and refilled in a step-wise manner.

The controller initiates each of the steps as the controlling process variables reach predetermined values. The sequence chart, Figure 2, shows the ten steps in one operating cycle. In sequence Step 1, chilling is started in the No. 1 drum. The rate of chilling is controlled by a *rate of temperature change* controller which throttles the propane gas to the compressors. A conventional cam in this portion of the rate of change controller continuously repositions the control point at a predetermined rate. The chilling of No. 1 drum continues through sequence Step 5. Also in Step 1, the No. 2 chiller starts discharging. The completion of the discharge step is indicated by a rapid rise in pressure in the filter feed tank. When the rate of pressure rise in this vessel reaches a preset value, as detected by a special rate-of-pressure-change recorder, Fig. 3, the sequence controller moves to Step 2, where the discharge valve closes for about 20 sec to allow the waxy stock remaining in the No. 2 chiller to flow to the discharge line. After 20 sec, the controller moves to Step 3, and the discharge valve opens again until the rate-of-pressure-rise instrument steps the sequence control to Step 4. During this step, the No. 2 chiller is warmed by introducing hot propane gas. When the chiller reaches a preset temperature, the sequence control moves to Step No. 5, and recharging starts. When the chiller is charged to the preset level, the charge valve closes. When the No. 1 chiller has been chilled to the preset temperature, the sequence control moves to Step 6, which is the counterpart of

FIG. 1. Batch-type process sequences from one chiller to the other, according to rate of change in temperatures and pressures.



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U. S. Navy Photo

Brand new in the Navy Bureau of Aeronautics, the Avionics Division is responsible for all aspects of research and development of electronic fire control and weapons launching equipment for Navy aircraft and guided missiles. This Division deals daily with problems undreamed of as recently as World War II. To ensure that our Navy air arm will continue to be the most effective and ultra-modern in the world, it plans in terms of 10, 15, or 25 years hence. Its personnel must think in terms of Mach 10 speeds or altitudes of 20 or more miles.

This vital R & D mission, which was formerly accomplished by the joint efforts of Armament and Electronics Divisions, has been merged in the Avionics Division to include a wide variety of electronic functions. Among these are ground station telemetering and instrumentation; guidance systems; warheads; fusing and launching of guided missiles; fighter attack systems; airborne early warning systems, and many others.

To coordinate the many programs under its jurisdiction, the Division has established a "Project Manager" system of organization. This system provides maximum streamlined operation and facilitates industry contacts as well. The personnel of the Avionics Division thus are enabled to develop with maximum facility the incredible electronic equipment needed by today's and tomorrow's aircraft and missiles. With their special knowledge and far seeing outlook, they will make certain that the new higher speeds, altitudes and ranges of aircraft are utilized to full effectiveness.

◀ **FJ-3 Fury goes aloft** from one of the after catapults of the U.S.S. Forrestal. An F2H-3 Banshee is in the foreground. Electronics developed by BuAer's Avionics Division provides planes such as these with their highly effective weapons and control systems.

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This is one of a series of ads on the technical activities of the Department of Defense.

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FIG. 2. Sequence chart for propane dewaxing process

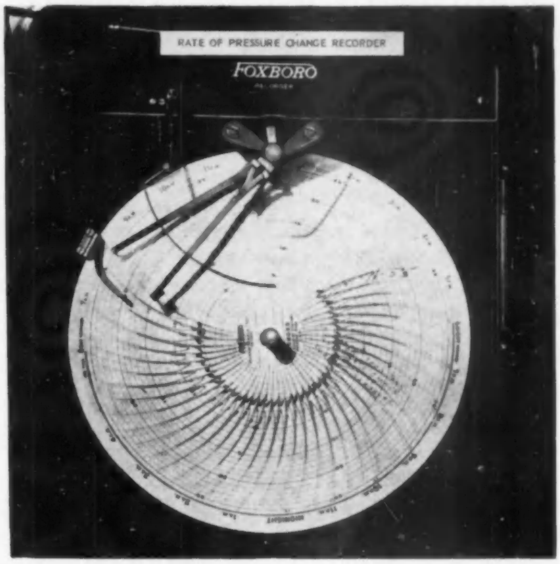

FIG. 3. Outer arm records rate of pressure change, initiates steps 2, 4, 7, and 9 of sequence.

Step 1. The half-cycle is repeated on opposite chillers, i.e., No. 2 chiller is chilled and the No. 1 chiller made ready for the next cycle. By the use of the sequence control system, the chilling of each batch is controlled precisely as the preceding batch.

Each of the two rate-of-chilling-temperature controllers is a conventional cam-type temperature controller, fitted, however, with a special reversible cam drive to permit the cam to reset automatically. An adjustable switch index is set to the minimum temperature desired for each batch, and the warm-up index is set to the maximum temperature desired prior to recharging. The rate-of-pressure-change recorder has two pens (Figure 3), the pen nearest the center recording the filter feed tank pressure, and the pen near the rim of the chart recording the rate-of-pressure change in the filter feed tank. This second pen mechanism closes a switch which steps the sequence control at the end of Steps 1, 3, 6, and 8. A hermetically sealed six-level, ten-position, telephone-type stepping switch controls the entire sequence. All other equipment is standard.

No difficulty was met during initial operation. A careful check-out of all components before startup and an extensive training program for operators and maintenance people during installation were credited for this. The service factor for the control equipment has been about 98 percent.

Differential Measurement Makes RF Fields Useful

WALTER H. BUCHSBAUM, Central Electronics Co.

Because electric fields are changed by the insertion of any new matter, whether conducting or dielectric, detectors and gages can be built that are based on these changes. Gages can be designed and calibrated to indicate the size, shape, or thickness of the material inserted, or to differentiate between materials. The key to such applications is differential measurement of the rf field. This article describes a detection application which protects a machine operator by stopping machine motion if he accidentally places his hand in a danger zone.

All materials, whether conducting or dielectric, cause a change in any ac electric field in which they are placed. Because an electromagnetic field is always associated with the electric field, ungrounded conducting materials absorb energy to supply eddy current losses so that the field is weaker on the side away from the radiation source. Grounded conducting materials become shields, and shunt the field away more readily. In dielectric materials, the propagation velocity of the electric field varies with the material, and causes a delay or phase shift in the field in which the dielectric is placed.

An rf amplifier (receiver) tuned to the frequency of the transmitter generating the field will note the presence

of conducting material by a reduced output. This reduction in output can close a relay to sound an alarm, start or stop some action, etc. This technique has not been used very much because its sensitivity is limited by rather large variations in the rf field due to transmitter oscillator instability, tube aging, changes in the humidity, barometric pressure, or temperature of the air forming the major part of the dielectric between the transmitting antenna and the receiving antenna.

These field variations due to transmitter instabilities and variations in the permittivity of the air can be eliminated by measuring the field near the transmitting antenna as well as at the receiving antenna. If the field variation is due to any of the causes above, both points in the field must change simultaneously, so that a differential amplifier, once balanced in the field, will remain balanced. On the other hand, a change in the field caused by insertion of some conducting material will reduce the field at the receiving antenna, but not at the transmitting antenna, thus unbalancing the differential amplifier.

The differential measurement technique can be illustrated by a simple electronic detection system which protects the operator of a hazardous machine from accidentally injuring himself. This system holds the distinction of being the first all-electronic operator-safety device ever approved by the Board of Standards & Appeals of New York State.

Safety devices for protecting the operators of hazardous machines have been invariably mechanical—physical barriers that keep the hands out of moving parts of the machine (and also often obscure vision), or two-hand releases which require both hands on the controls. These protect the operator, but unfortunately they usually hinder his work and slow down his production. Thus, operators on piece work often consider them a nuisance and find ways to remove or circumvent them. Light beams and photocells are less of a nuisance, but are practical only where the danger area can be defined by straight lines and where rather narrow beams are sufficient.

The electronic guard uses a radio frequency field to envelop the danger zone. The field is defined by the transmitting and receiving antennas, which are shaped to enclose the guarded area, as in Figure 1, and can easily be bent around corners. The figure also shows that the pickup loop that monitors the field is so located near the transmitting antenna that the field between the two is not affected during normal operation of the machine. Figure 2 shows such an installation on a small punch press used for eyeletting belts and straps for pocketbooks, brief cases, etc. In this application, the eyelets are fed by hand since production runs are rather short and require a large variety of eyelets, snaps, and other metal trimmings to be inserted on the machine.

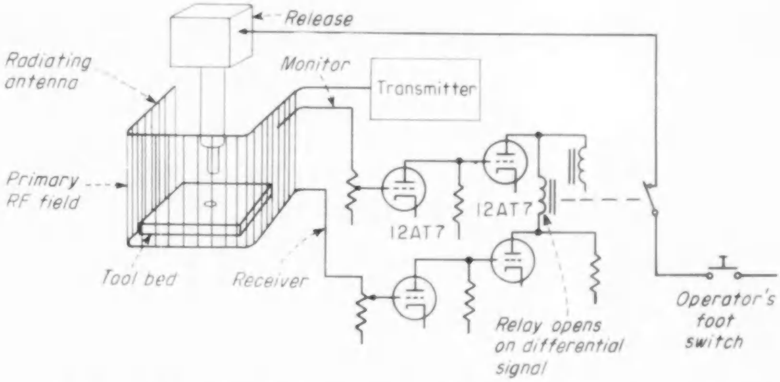

FIG. 1. Rf electronic guard operates on change in differential between monitor and receiver antennas. Note that monitor antenna is in field but not in guarded area.

Since this particular application works by measuring the reduction in field at the receiving antenna due to absorption in conducting materials, the plastic material being eyeletted causes no change in the field, but the operator's hands do. Figure 1 also indicates the major details of the circuit used. Note that the monitor coils are in the field near the transmitting antenna but outside the guarded area.

The system is aligned for proper operation by first tuning the two antennas and the monitoring coil to the frequency of the transmitter (in this installation 27.55 mc). Then the transmitter output is adjusted to give a good signal at the receiver input potentiometer (about 3 volts on this machine). With nothing in the guarded area, the receiver and monitor potentiometers are adjusted to give the same voltage at the plates of the following parallel stages, or zero differential across the control relay. Sensitivity of the electronic guard is set by adjusting both potentiometers together.

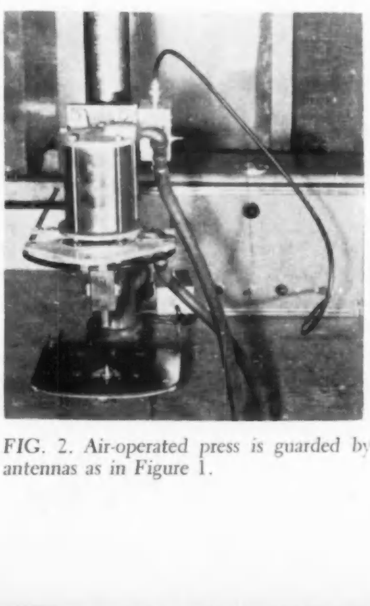

FIG. 2. Air-operated press is guarded by antennas as in Figure 1.

System operation

Aside from a disturbance in the guarded area, the only change in received signal can be due to atmospheric changes or to variations in the output of the transmitter oscillator. Either change will affect the monitoring signal as well as the received signal, so that the two grids of the first 12AT7 remain in the same ratio, and the differential between the plates of the second 12AT7 stays at zero. Insertion of the operator's hand into the guarded area, on the other hand, reduces the field to the receiving antenna without affecting the monitoring; this unbalances the system and opens the control relay.

Not shown, but essential to the acceptance of the system as an operator safety device, are several circuit features which make the system fail safe.

Other applications

As stated earlier, dielectric materials cause a phase shift in the electric field in which they are placed. Since this phase shift also varies with changes in the permittivity of the air due to humidity, pressure, etc., differential measurement is necessary for this application. Phase discriminators provide this measurement, the phase between the transmitting and monitoring antennas being used as the reference phase. With available phase discriminators, it should be possible to measure the thickness of dielectric materials within about 0.1 percent.

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Extend Range and Retain Accuracy With Vernier Technique

JOHN P. O'CONNOR
Naval Research Laboratory

This magnetic-disc timer for sonar computers uses a second disc as a vernier on the first to measure times from 10 millisec to 20 sec to a 2-millisec accuracy.

In sonar, target range is determined by exactly measuring the time required for sound to propagate from a transmitter to a target and back. Because this interval may be as long as 20 sec (15,000-yd range) and a new pulse is not transmitted until the last has returned as an echo, fire control computers are used that continuously calcuate the intermediate positions of the moving target. The sonar data are then used to correct the computer. One way to correct the computer is to produce a simulated "echo" pulse at the computed range, as measured from the transmitted pulse, and use the time error between this pulse and the real echo as the correction signal. The vernier timer produces this "echo".

The timer is a magnetic recording device that writes a pulse on one side of a thin spring steel disc and reads it later with a second head on the opposite side. The principle of operation can be understood from Figure 1. The write head is fixed and the read head is positioned relative to it by the computer, according to the computed range. The disc is driven at constant speed so that, by writing a pulse when the transmitter is keyed, a simulated echo will be produced by the read head after a time dependent on the angular displacement of the two heads.

Since the shortest time interval that must be measured by this system is about 10 millisec, a reasonably high disc speed must be used if the heads are to have a repeatable angular separation for short intervals. On the other hand, the longest interval, as mentioned before, is about 20 sec. This requires that the timer be accurate over a 2,000-to-1 range!

Vernier disc system

This problem of high accuracy over an extreme range was solved by adding a vernier disc and a pulse coincidence circuit, as shown in Figure 2. The second disc is driven at 99 percent the speed of the first, and its read head is positioned at 99 percent of the angle of the first read head. A simulated "echo" can be produced by this system only when pulses from both read heads coincide in time.

For each revolution of the high-speed disc, the low-speed disc falls behind 1/100 of a revolution. The read heads are positioned similarly—the "high-speed" read head makes 100 revolutions for 99 revolutions of the "low-speed" head. Thus, the maximum time interval between coincident pulses is the time required for 100 revolutions of the high speed disc. If the high-speed disc rotates (as in the model) at 5 rps, the maximum time interval is 20 sec.

Vernier system operation

Zero computed range is represented when both read heads correspond exactly with both write heads. The read head positions shown in Figure 2 can obtain only during the first revolution of the high-speed read head. This position represents a very short range—pulse coincidence would occur on the first revolution of the high-speed disc. As the read heads are moved to longer and longer computed ranges, however, the "slow" read head falls back farther and farther for each revolution of the "fast" head. This requires that the fast disc make more and more revolutions before the pulse on the slow disc falls back to the "slow" read head and the pulses can coincide in time.

The accuracy of this timer depends on the constancy of speed of the disc drive motor. A synchronous motor was used to drive the disc, but the line frequency varied too much over short time intervals, and a special constant-frequency power supply using a 60-cps tuning fork oscillator had to be used. With this power supply, the timer was found to be accurate within plus or minus 2 millisec over the entire measurement range. This compares favorably to the 1 part in 10,000 accuracy of the tuning fork itself.

Another difficulty observed was that pulses would be inductively coupled from the write heads to the read heads when the heads were close to each other. This was solved by adding a relay that closes when the write heads are pulsed and remains closed for the rest of the cycle. The read head outputs are passed through this relay. Because the relay closes 2 or 3 millisec after the write pulse, no output pulses appear until true coincidence.

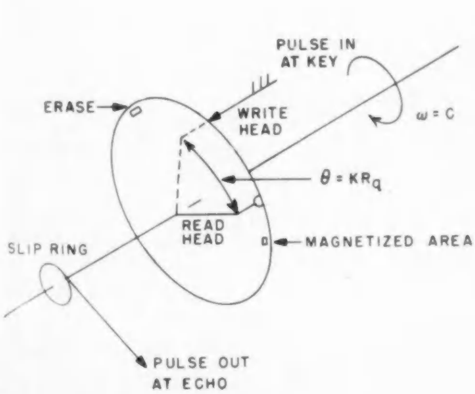

FIG. 1. Single-disc magnetic timer.

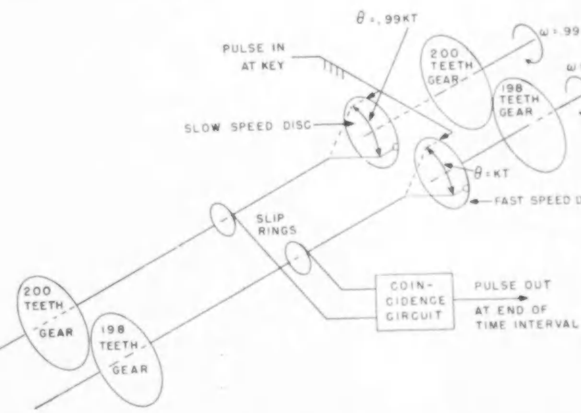

FIG. 2. Two-disc vernier timer requires coincidence between pulses from both discs.

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THIRD OF A SERIES

Why reliability engineering is not enough

There's more to reliability than meets the eye ... a thousand inspectors cannot put reliability into an item that is inherently weak in engineering or production design ... highest reliability in a component is obtained only when the manufacturer is aware of the problems in obtaining reliability ... plus providing a proper climate in which employees are motivated by pride in product to surpass specifications.

In our humble opinion, the building of reliability into a product requires an alert *awareness* of the many, many facets of the problem. We'd like to submit these . . .

- ✶ ***"Integrity of intent" on the part of the manufacturer to meet the problems . . . coupled with provision of a proper climate for the carrying out of reliability objectives***
- ✶ ***Financial ability to take the necessary steps***
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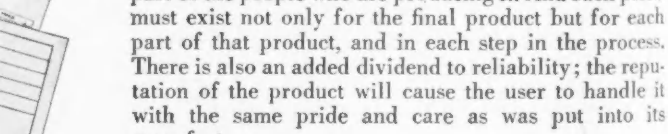
- ✶ ***Collection, in the field, of failure data, analysis, and corrective action***
- ✶ ***All of these facets in depth***

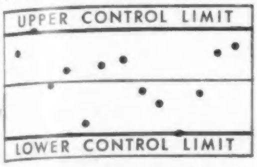
Important as all of these are, the most important is the provision of proper climate, in the form of spirit and attitude of all personnel in pride of product, to carry out reliability objectives. In preceding articles in this series we've touched on some of the more technical aspects of reliability engineering. The manufacturer must naturally have an awareness of the problem, the integrity of intent to turn out the best product it can for a particular market or application, the financial ability to establish a Reliability program, the management ability to install it, the necessary manufacturing equipment and engineering organization to carry it out. But *all of these are not enough, if they are not instituted in a climate where an attitude will prevail that makes such things effective.*

The manufacturer's integrity must necessarily be carried out, also, in the design, in manufacturing, and in finally warranting the product created ... but, again, with every man and woman in the organization trying to meet or exceed the standards that have been created. This latter aspect we call "pride of product" on the part of the people who are producing it. And such pride must exist not only for the final product but for each part of that product, and in each step in the process. There is also an added dividend to reliability; the reputation of the product will cause the user to handle it with the same pride and care as was put into its manufacture.

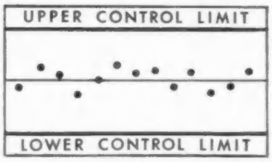
It is interesting that people who are proud of a product, and enjoy what they are doing, can keep closer tolerances on the parts they work with and produce than those who are merely working for their pay. An assembler, who's proud of the product turned out, sees questionable components and avoids putting them into the assembly, while a disinterested person leaves them for "inspection" to catch. It is interesting in this connection, too, that some of the finest watch



parts made in Switzerland are produced in little shops where modern quality control techniques are unheard of . . . produced by a craftsman whose major technique is pride in his work . . . and thereby builds everything to the exacting tolerances required.



Quality control graph . . . without pride in product.



Quality control graph . . . with pride in product.

The atmosphere here at Cannon, since our inception in 1915, has included a design and manufacturing philosophy embracing the highest quality and reliability in each Cannon Plug for the specific application for which it is to be used. *To these principles all Cannon Plugs are built*! Even on connectors designed to customer or MIL-spec we constantly strive to give even more . . . to increase the safety factor . . . to give that "something extra" according to our own high "Cannon Standards", as exemplified in our Cannon Credo.

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TO DEVELOP ***and produce products of such quality, and render such service, that we may always be proud of our efforts.***

TO MARKET ***the product of our endeavor at a reasonable profit for continuing growth, reward for effort and a return on investment.***

TO ACCEPT ***our responsibility to our community, our country, and our fellow man.***

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Sales Engineers . . . fully qualified technical men who contact our customers.

Design Engineers . . . specialists in past and present design methods who analyze failure data caused by design inadequacies and initiate corrective action.

Development Engineering and Model Shop Group . . . specializing in the development of prototypes. In these Laboratories, your prototype is tested to see that all specifications are met . . . physical, operating, environmental. Test reports are made up, and presented to you for review and approval. Not until all these steps have been taken is your order placed in production.

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Quality Control Group . . . well qualified to administer the high requirements of "Cannon Standards" . . . staffed by well trained inspectors and analysts equipped with the most modern equipment.

Quality Engineering Group . . . handling the technical aspects of sampling plans . . . preparing inspection and test procedures to realize the customer's desired quality level and the over-all quality level of the entire Cannon manufacturing operation. Materials are processed through receiving inspection. Process, re-work and final inspection barriers are set up. In addition to standard Military and Cannon manuals of quality control procedures, specific jobs . . . such as yours . . . may require additional special inspection or testing. If so, these requirements are established throughout the process, and where necessary, coordinated with you. Our failure data collection and analysis in this field has given us intimate knowledge of the critical points at which such control should be used. Recognized statistical control procedures are used both in process and at the inspection points.

Materials and Processes Laboratory Group . . . working in both the research and production phases. This is the group that checks performance of new designs, constantly investigates new materials and processes, and (over and above normal manufacturing supervision and quality control operation) runs continuous reliability and assurance tests on the manufacturing cycle.

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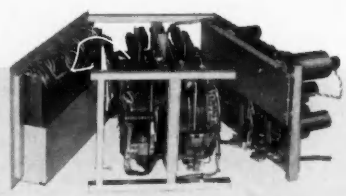

UNUSUALLY EASY TO SERVICE

The one-piece hood houses three distinct sub-assemblies: amplifier, power and reference supplies; balance circuit; and read-out. Each sub-assembly is pivoted for excellent accessibility to all parts.

SPECIFICATIONS

Display: four digits, polarity, decimal point.
Range: 0.001 - 999.9 volts dc.
Ranging: automatic.
Polarity: automatic.
Accuracy: 0.05%, ±1 digit.
Input impedance: 11 megohms.
Average balance time: 1 second.
Calibration: self-calibrated.
Stability: 0.003%/C°.

The complete line of digital instruments

ELECTRO INSTRUMENTS INC.
3794 Rosecrans Street, San Diego, California

Financial Aid to Higher Education

A Fine Start, But...

This editorial has two purposes. The first is to salute American business for the fine start it has made in helping to relieve the financial plight of our colleges and universities. The second purpose is to stress the importance of having business provide more financial aid, and soon.

How Business Helps Higher Education

Business contributions to higher education doubled between 1950 and 1955. They jumped from $40 million to $80 million. Preliminary figures indicate they will be even higher this year.

Business firms have also shown a lot of ingenuity in devising different ways of making their contributions. The methods range from a matching of an employee's contribution to his particular alma mater to wide diffusion of the money through state and regional money-raising associations of colleges and universities. Thanks to this ingenuity, business firms now have a wide choice of ways by which to give effective aid. The way most appreciated by college administrators is the making of gifts unrestricted as to the purpose for which the money is used.

Imposing as it is, however, what business has done thus far is only a good start. Only a tiny fraction of the total number of business firms in the country are giving direct financial help to our colleges and universities; and this fraction includes fewer than half of the hundred largest corporations in the country. Also, the amount of financial help being provided by business constitutes only a very small fraction of what is needed.

Why Colleges Need More Aid

Right now our privately endowed colleges and universities need about $350 million more in operating income a year than they are receiving to enable them to pay decent faculty salaries and be in tolerably good working order otherwise. The reasons, including a severe decline in the purchasing power of their endowment income because of price inflation, have been dealt with in the previous editorials in this series.

In addition, these institutions, together with the tax-supported schools, are faced with a tremendous increase in enrollment over the years ahead. With both a rapidly increasing population of young people and an increasing propor-

tion of them going to college, this year's enrollment of 3.2 million students is expected to reach 4.0 million by 1960, and to be doubled by 1970.

For the next ten years our privately supported colleges and universities must have an average of about $400 million a year above what they can be expected to collect from tuition fees, income from endowment funds, etc.

This figure of $400 million does not include what is needed for new buildings and equipment. It also does not include help for tax-supported schools above what they get from taxes, fees, etc. Business has given and will continue to give these schools substantial aid. Indeed, almost 25% of the financial help from business for our colleges and universities went to tax-supported schools in 1955.

If aid from business met their needs for increased operating income, the privately supported colleges and universities would be given a decisive lift in performing successfully their part in our system of higher education. They would still have large needs of capital equipment — buildings, dormitories, laboratories — but help from other sources, such as that provided by devoted alumni, where they are well organized, could be expected to go far toward meeting these needs. Also some companies prefer to concentrate on meeting needs of this type.

What 1% of Profits Would Do

But do business firms have the capacity to fill the gap in adequate operating income for our privately endowed colleges and universities without putting an excessive financial burden on themselves? Those who have studied this capacity carefully say that the answer clearly is yes. If, of its profits before taxes — last year an estimated $43 billion — business were to devote 1% to helping our privately endowed colleges, it would take care of present operating needs of about $350 million a year. And the balance of $80 million would be a big step in meeting their needs for new buildings and equipment, too.

About one half of a 1% contribution of this sort would, in effect, be made by the federal government. Up to a limit of 5%, contributions of this type are exempt from the federal corporate income tax. For corporations with incomes above $25,000 per year this tax is 52%.

It is clear that not all business firms are in shape to devote 1% of their profits to aid to higher education. Even in this year of record-breaking prosperity, many of them will have no profits at all. But if business generally would take 1% of pre-tax profits as a target or benchmark for financial help to our privately endowed colleges and universities these institutions would again have sturdy financial foundations.

Relatively this is a very small price to pay (1) to insure a continuing supply of competently trained young men and women and (2) to buttress our freedom by assuring the successful survival of the privately supported sector of our system of higher education.

This is one of a series of editorials prepared by the McGraw-Hill Department of Economics to help increase public knowledge and understanding of important nationwide developments of particular concern to the business and professional community served by our industrial and technical publications.

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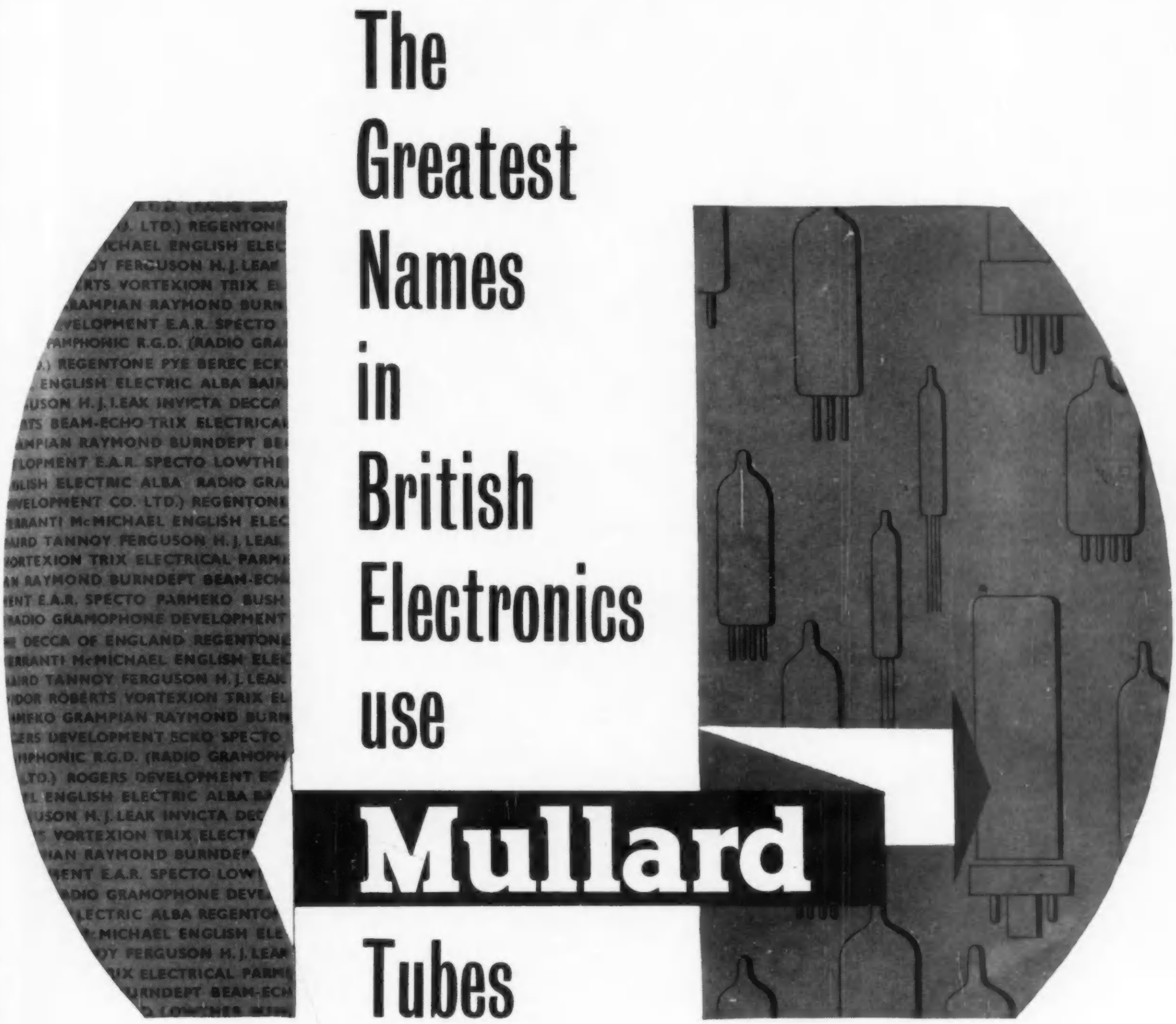
Donald C McGraw
PRESIDENT

McGRAW-HILL PUBLISHING COMPANY, INC.



British equipment manufacturers are making a vital contribution to the development of electronics in all fields of application.

Their products are being exported to every corner of the world, earning a universal reputation for advanced techniques and excellent performance.

The majority of these electronic equipment manufacturers consistently use Mullard tubes. This choice is decided upon because they prefer the greater assurance of efficiency and dependability, and because the vast manufacturing resources of the Mullard organisation guarantee ready availability of Mullard tubes wherever they are needed.

Supplies of Mullard tubes for replacement in British equipments are available from the companies mentioned below:—

In the U.S.A.
International Electronics
Corporation,
Department CZ,
81, Spring Street, N.Y. 12.
New York, U.S.A.

In Canada
Rogers Majestic Electronics
Limited,
Department CB,
11-9 Brentcliffe Road,
Toronto 17, Ontario, Canada

Mullard

Electronic Tubes — used throughout the world

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Mullard is the Trade Mark of
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MEV 45

Creative Engineers:

Work where imaginative engineering becomes intelligent hardware...in quantity!

It takes a special kind of scientific imagination and engineering freedom to develop and design intricate automatic systems for inertial guidance, flight control, armament control and data processing. At AUTONETICS, your opportunity to be creative in these fields is practically unlimited—because you know your ideas can be brought to life on the production line.

LABORATORY PERFECTION COMES TO THE ASSEMBLY LINE

To build just *one* of these electromechanical brains or muscles is a technological triumph. But today—with facilities and standards of precision that rival those of an operating room —AUTONETICS is delivering these advanced and reliable systems at a quantity-production pace.

TOOLS AND TECHNIQUES TO IMPLEMENT YOUR IDEAS

AUTONETICS' precision machine shops are capable of millionths of an inch precision in either developmental or volume quantities. Electronics capability includes micro-miniaturized components, complete computers and transistorized circuits. AUTONETICS' new, modern facilities include an Autonavigation Building which provides the precisely controlled environment for large-scale development and manufacture of advanced inertial guidance systems. Extensive production and development test equipment includes automatic electronic check-out systems and the latest environmental equipment... as unique as the electromechanical controls they evaluate.

ARE THESE THINGS IMPORTANT TO YOU?

Do you need the engineering freedom that this kind of production capability creates? You can have it at AUTONETICS —one of the few companies in the world that can design and quantity-produce complete automatic control systems for both military and industry.

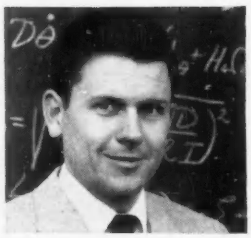
LET US KNOW what kind of creative engineering interests you (please include highlights of your education and experience).

Write today to: Mr. W. D. Benning, Engineering Personnel, Dept. 991-CO
AUTONETICS, Box AN, Bellflower, Calif.

THREE AUTONETICS ENGINEERS ON THEIR WAY UP

In just 6 years, Elliott Buxton has risen from Servo Research Analyst to Group Leader responsible for Preliminary Engineering in Autonetics' Flight Control Program. Among his other professional achievements, "Buck" has several patents filed in his name – including an aircraft maneuver stabilizer and a load-factor anticipation switch.

Ronald Greenslade (BSEE Michigan) is Group Leader in charge of development and design of electro-mechanical components for aircraft armament control systems at Autonetics. From Southern California's many fine residential communities, Ronald chose Long Beach, where he lives with his wife and two young daughters.



Dave Kimball joined Autonetics in 1950 with a BSEE from the University of New Mexico. Only 29, he is already Group Leader in the challenging field of Inertial Guidance Engineering. Dave lives with his wife and two children in nearby Fullerton, California – an ideal center for his favorite diversions: softball, bowling and skin-diving.

Autonetics
A Division of North American Aviation, Inc.

AUTOMATIC CONTROLS MAN HAS NEVER BUILT BEFORE

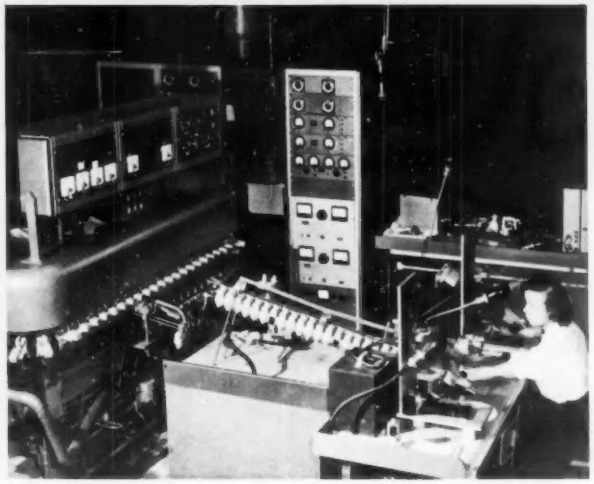
NOW IN MASS PRODUCTION AT SPRING CITY, PA.

PHILCO *Transistor Center, U.S.A.*

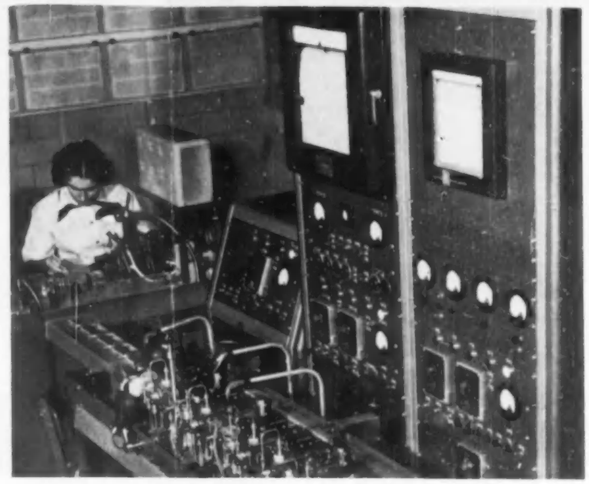
For the first time, the dream of the electronic industry comes true . . . made possible by many years of Philco pioneering, research and production of semi conductors. Philco's great new transistor plant at Spring City, Pa. is designed for and dedicated to the mass production of reliable transistors.

← *Lift the Page and read this important news!*

An exclusive machine, designed by Philco engineers. It's a Surface Barrier Transistor Lead Attacher which feeds, cuts, plates, precisely positions and automatically solders the whisker wire to the transistor emitter and collector.



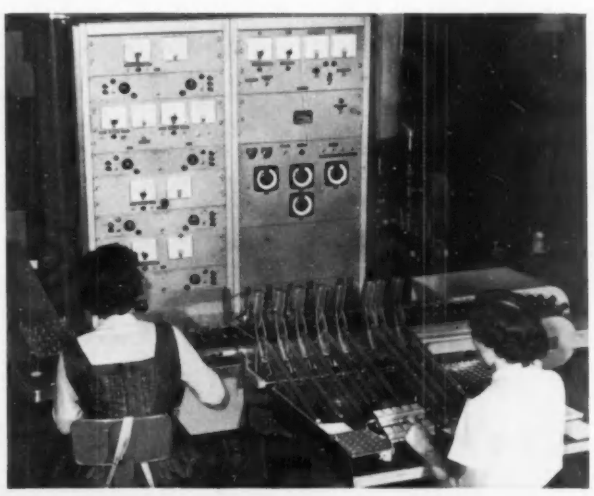
New Philco automatic "Carousel" assembles and processes alloy junction type transistors. It prepares stems by localized plating, solders stems to transistors, solders leads to emitters and collectors, and follows with electrolytic clean-up etching, dip rinsing and ultra sonic rinsing to remove contaminants.



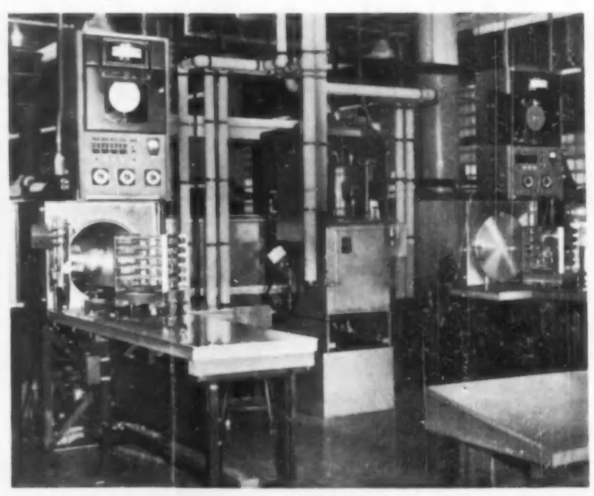
This exclusive Philco Automatic Transfer Machine performs nine operations in the manufacture of surface barrier transistors. Following each step is a rinsing operation, and finally—hot nitrogen drying. Critical operations are automatically monitored and recorded for quality control.

Shown below is a portion of the Life Test Section where all types of Philco transistors are tested under a variety of storage and operational conditions. Individual test positions are provided for over 10,000 units.

The new Spring City Transistor Plant is unmatched for advanced testing methods. Below is a Philco designed high speed Automatic Test Facility for testing seven parameters of power transistors.



Unsealed power transistors in large batches go into vacuum oven (shown below at left) for baking, while simultaneously caps go into vacuum oven (shown at right). After baking cycle the transistors roll on carriers into dry box for cold weld sealing.



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Creative Engineers:

Work where imaginative ...eering becomes intelligent hardware...in quantity!

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...Y PERFECTION ...UE ASSEMBLY LINE

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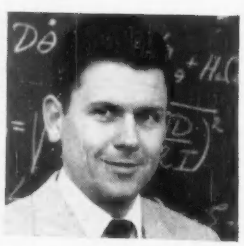

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Autonetics

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An exclusive machine, designed by Philco engineers. It's a Surface Barrier Transistor Lead Attacher which feeds, cuts, plates, precisely positions and automatically solders the whisker wire to the transistor emitter and collector.

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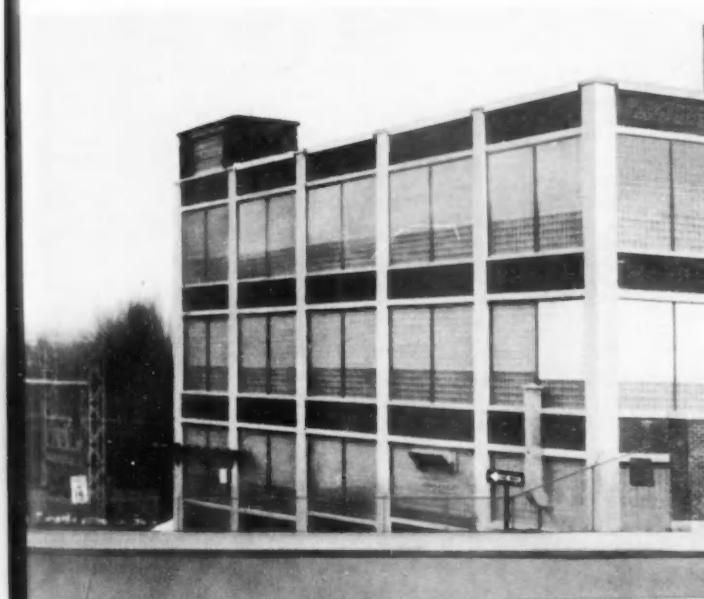

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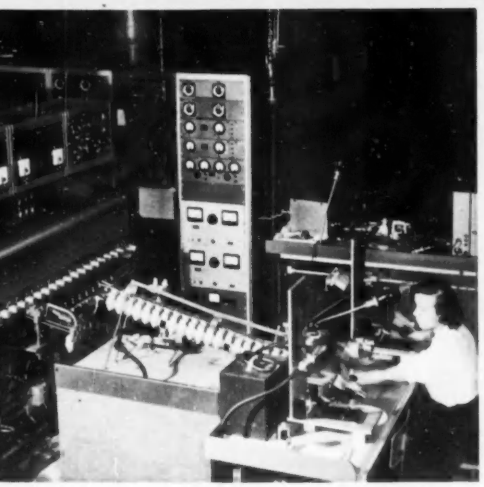
The new Sprin... advanced testing... speed Automati... of power transis...

WITH THIS GREAT NEW AUTOMATED PLANT

PHILCO

revolutionizes production methods and sets new quality standards in the transistor field

It's the greatest development in transistor history. A complete plant, housing the most advanced transistor manufacturing equipment and utilizing entirely new production methods, is now in mass production at Spring City, Pa. We call it Philco Transistor Center, U.S.A.—and, that's exactly what it is. From this plant come the world's finest transistors—unmatched in quality and reliability.



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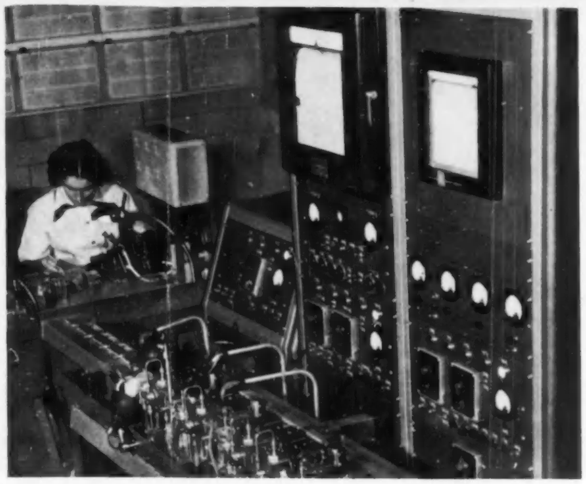

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100,000 square feet of area devoted exclusively to semi conductor production. This plant is equipped with centralized supplies of de-ionized water, vacuum, disassociated ammonia, hydrogen, nitrogen and high purity compressed air, plus complete air conditioning with dust and humidity control.

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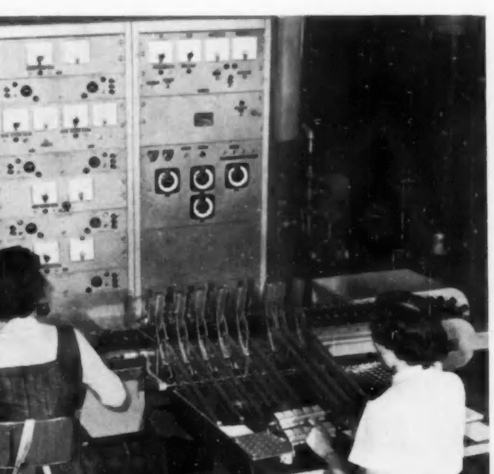

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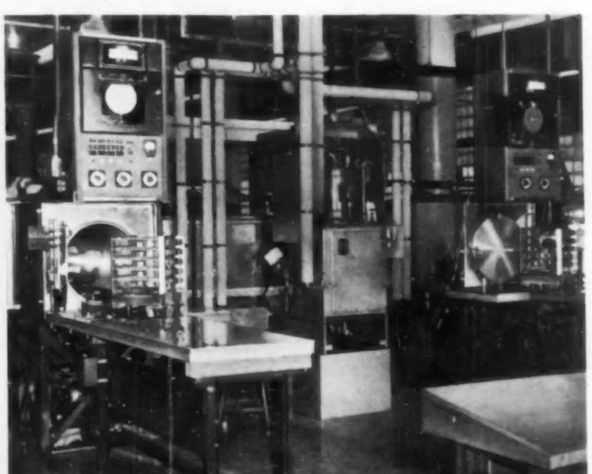


NEW METHODS Extensive research, design and planning by Philco engineers has resulted in completely new and far superior transistor production methods. Mass production is now a reality, and special equipment results in closer devise tolerances.

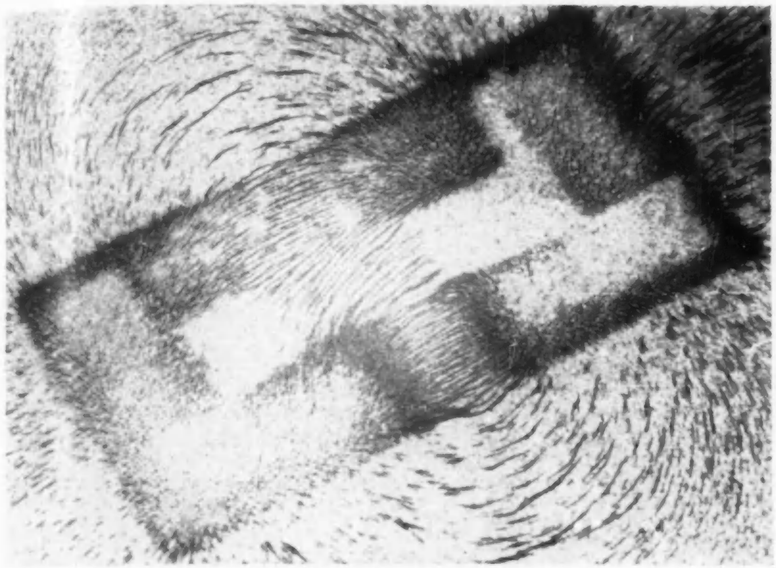
NEW MACHINES Designed specifically for the new mass production methods at Spring City, Pa., machinery completely new in concept is now in operation, with the finest precision control in the industry. These new machines have been designed with the flexibility to accommodate future advances in the transistor field.

NEW AUTOMATION The result of this new production machinery is automation—more automation than ever before in the transistor field. This automatic equipment eliminates human error, increases production capacity and minimizes contamination.

NEW TEST CONTROLS Automatic test equipment, designed by Philco engineers, tests each transistor at every stage of fabrication. Each vital performance parameter is accurately tested. Environmental and life tests assure utmost reliability.

See Back Page FOR DETAILS ON PHILCO TRANSISTORS

Answer: Generally, this is true. However, structural considerations may prevent the placement of permanent magnets at preferred positions.



Flux pattern of experimental magnetic circuits

How location of magnets affects magnetic circuits

Adapted from an article by Charles A. Maynard, vice president, Research and Engineering, The Indiana Steel Products Company

The LOCATION of permanent magnets in a magnetic circuit is a definite factor in design. To determine the extent to which this is true, involved calculations are necessary.

A comparatively simple experiment, however, which shows the nature of the changes that take place when permanent magnets are placed in different positions in a magnetic circuit, was devised by Mr. Maynard. The material on which the following questions and answers are based was taken from a report, "An Experiment in Magnet Location," published in Vol. 3, No. 5, of Applied Magnetics. *A copy of this issue is available on request to The Indiana Steel Products Co., Dept. P-2. Valparaiso, Ind.*

Question: What effect does the location of permanent magnets have on a magnetic circuit?

Answer: It has a marked influence on the flux density in the various portions of the magnetic circuit.

Question: Is there a preferred location for magnets?

Answer: Yes, it is important to place the magnets as close to the air gap as possible.

Question: What is the benefit of their location?

Answer: The leakage flux is reduced, and the useful flux in the air gap is increased.

Question: How is this an important factor in design?

Answer: It minimizes the amount of magnet material required to produce a given flux in the air gap.

Question: Does this mean lower magnet costs?

Answer: Generally, this is true. However, structural considerations may prevent the placement of permanent magnets at preferred positions.

Question: Are there available quantitative data which indicate the degree to which magnet position influences the efficiency of a circuit?

Answer: A brief experiment was conducted on the nature and magnitude of the changes that occur when magnets are placed in various positions in a simple magnetic circuit. The results are discussed in *Applied Magnetics*, Vol. 3, No. 5.

World's largest permanent magnet separates electron particles

The largest and most powerful permanent magnet ever designed is an important part of a new Mass Spectrometer to be used for high molecular weight hydrocarbon analysis at the Whiting, Indiana, research and development laboratories of a large Midwestern oil company. Function of the spectrometer is to establish a strong magnetic field that separates electron particles.

Indiana's C. A. Maynard inspects air gap of giant Alnico V magnet assembly

The Alnico V permanent magnet used in the assembly has a maximum field strength of 6,000 gauss . . . equal to 10 tons of magnetic holding force . . . and weighs 1,300 pounds. The complete assembly, which weighs approximately 4,700 pounds, was designed and fabricated by The Indiana Steel Products Company, Valparaiso, Indiana.

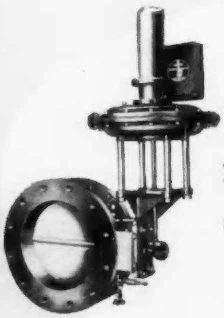
GET THE BEST SO

Needle Valves

Rugged, outstanding performers for proportional control of small flows. Interchangeable seat rings and plugs. For water, gas, steam, chemicals. Trim and body materials available for "difficult" fluids. Shown here with unique *reversible* Stabilflo Motor.

Saunders Type Valves

A complete line, particularly suited to handling of highly corrosive fluids, or fluids containing solids in suspension. Available with Stabilflo Motor as shown, or with Stabiload Cylinder and Power Positioner.

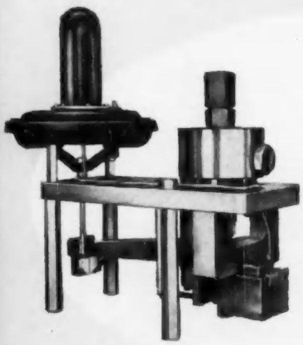


Butterfly Valves

Light and heavy duty types, with angle or swing-through seating, in spool or wafer body style, for low pressure air, gases in combustion control, steam, high pressure gases and liquids, etc. Available with Stabilflo Motor (shown) or cylinder operator.

Gate Valves

Guillotine-type slide valves, specially designed to handle pulp fibre, slurries, and similar fluids. Available with Stabiload Cylinder and Power Positioner as illustrated, for throttling service, or with 4-way pilot valve for on-off service.



Super-Pressure Valves

For throttling or let-down service up to 30,000 psi. Features an exclusive high-pressure bellows seal. Port sizes and connections to meet high pressure process specifications.

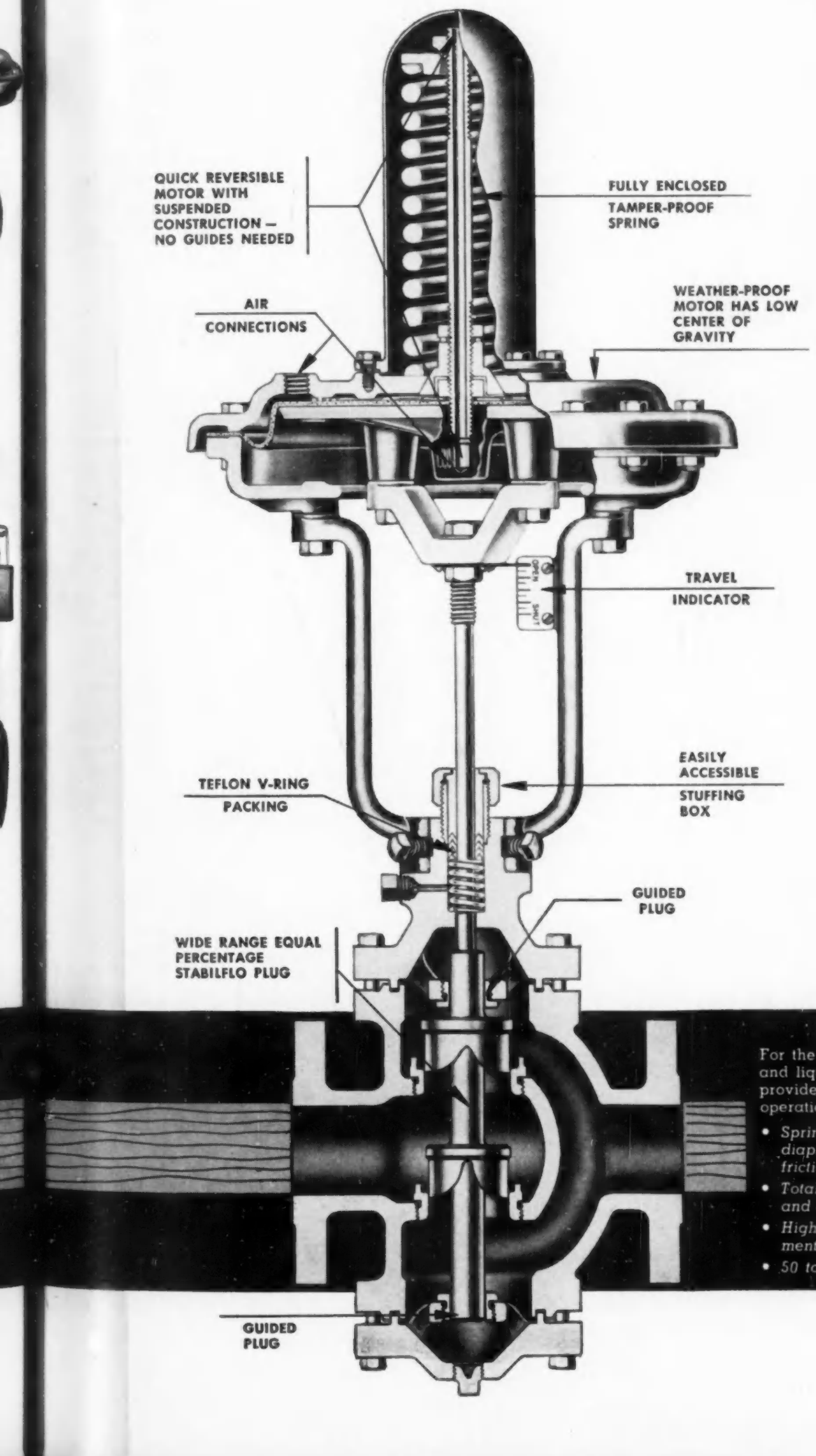
FOXBORO CONTROL VALVES

Reg. U.S. Pat. Off.

8 Strategic Branch Shops for Coast-to-Coast Service: **Pittsburgh, Pa. • Chicago (Skokie), Ill. • Dallas, Tex. • Houston, Tex. • San Francisco (San Leandro), Cal. • Los Angeles, Cal. • Montreal, Que. • Vancouver, B. C.**

SOLUTION TO YOUR CONTROL VALVE PROBLEMS

...with Foxboro Pneumatic Control Valves



You can always be sure of getting the control valve best suited to flow conditions and control actions when you specify Foxboro. No other single source offers such a wide variety of control valves for specific applications. None other has Foxboro's experience in applying them — in every phase of industrial processing.

Your choice extends from valves for simple on-off control at one extreme, to specialized proportioning control at the other; for high vacuum work to operation at 30,000 psi; for temperatures from —350° to +1000°F. And there's a wide choice of plug designs — and of alloys and trim to handle even severely corrosive and erosive fluids.

You can save shipping cost and time, too, buying direct from Foxboro's strategically located branch shops. They're staffed by experts.

A few typical control valves from Foxboro's complete line are illustrated here. For full details, or specific information on your problem, call your nearby Foxboro Field Engineer or write The Foxboro Company, 362 Norfolk St., Foxboro, Mass.

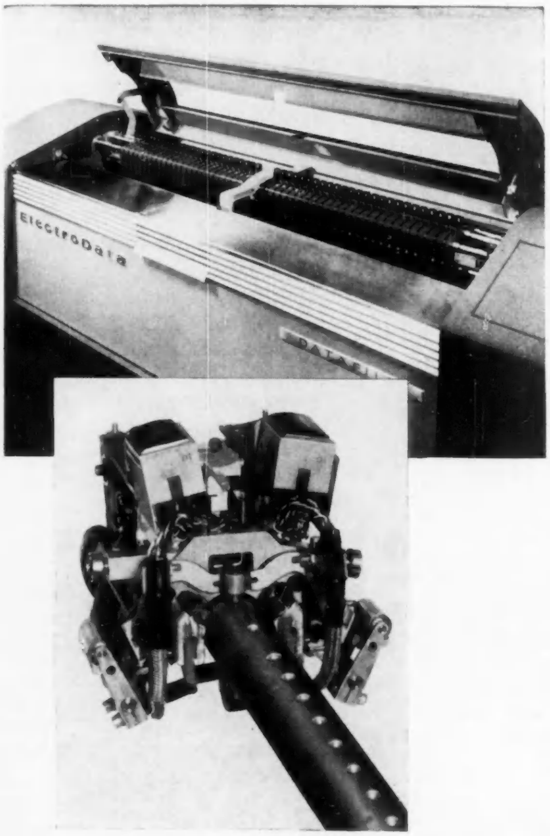
STABILFLO CONTROL VALVES

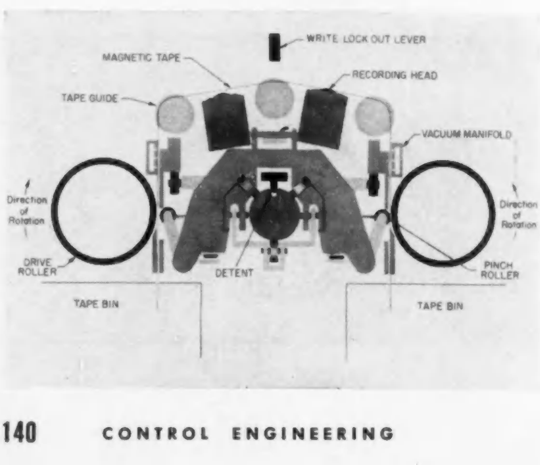
For the great majority of temperature, pressure, flow, and liquid level control applications, this basic valve provides unsurpassed sensitivity and troublefree operation. Unique design features:

- *Spring-above-diaphragm construction makes diaphragm motor self-aligning, virtually free from friction and hysteresis.*
- *Totally enclosed spring protects against tampering and corrosion.*
- *High-lift wide range V-port provides greater increment of lift for given change in air pressure.*
- *50 to 1 rangeability - equal percentage characteristics.*

NEW PRODUCTS

LISTING IN GROUPS



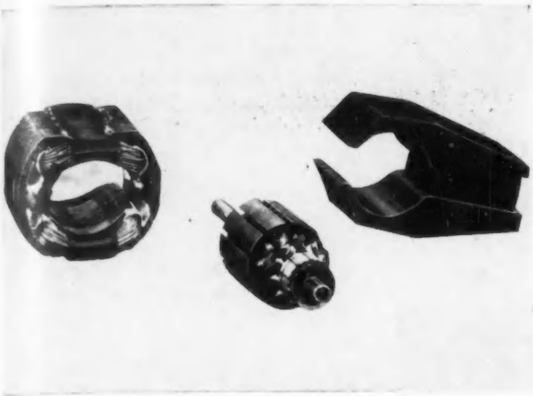


"DATAFILE" stores 22,000,000 characters, has average access time of 15 sec.

Five times the capacity of a standard magnetic tape unit and one-tenth the access time for less than twice the cost! These are approximately the figures that apply to ElectroData's new medium-speed random access storage system, dubbed "Datafile". More specifically, each Datafile unit can store 22 million characters, and the average access time from any point in the memory to any other point is under 15 sec for a completely filled memory, decreasing to 2 sec for 10 percent of capacity. The buying price is about $25,000. Up to ten Datafiles may be connected to the central computer, providing a memory of nearly a quarter-billion characters.

Rather than use large, continuous recording surfaces like drums or discs, ElectroData engineers chose easily available, low-cost, ¾-in. mylar tapes. These tapes are arranged in parallel as 50 separate 250-ft lengths, stored loosely in 50 pairs of bins. The arrangement of the tapes can be seen in the top photograph. Taken together, the tapes are equivalent to a surface 3 ft long by 250 ft wide, with parallel recording lanes that can be reached by a servo-positioned reading head. The system has this advantage over the continuous surface, however: each lane can be searched independently without moving all the other lanes, thus making it possible in many applications to arrange the data in a particular lane so that the most-referred-to items lie near each other, effectively reducing the access time. To read a particular tape, the head assembly shown in the drawing is servo-driven to that tape, then precisely positioned by a mechanical detent. A pinch roller then arbitrarily connects the tape to one of two counter-rotating drive rollers that run the length of the machine. The first few addresses read determine if the arbitrary starting direction is approaching the selected address; if it is not, the tape is reversed immediately to reach the selected address in the minimum time. The two heads are used because each tape carries two six-channel interlaced lanes, as in the standard Datatron tape units. Thus, there are 100 selectable data lanes on the 50 tapes, each lane divided into 1,000 blocks of 220 characters. Four channels contain a binary-coded decimal digit, the fifth a parity code, and the sixth marks blocks of 20 11-digit computer words. The read-record head assembly is driven by an error-rate-damped servo from a precision dc bridge, and its average random traverse time is just under 1 sec, corresponding to travel of 17 tapes.—ElectraData Div. of Burroughs Corp., Pasadena, Calif.

Circle No. 1 on reply card



"INDOX V" saves weight and space.

Indox V, a new oriented ceramic permanent magnet material, produces a very high peak energy product and permits substantial weight saving. Made of a ferrite magnetic material, oriented in the direction of pressing, Indox V has a peak energy product of about 3.5×10^6.

On an equivalent weight basis, the energy of Indox V is comparable to that of Alnico V, and because of its high coercive force (2,000 oersteds), the required length is only 28 percent that of Alnico V at optimum operation. Residual induction of the new material is 3,840 gausses. At the point of peak energy product, flux density is 1,920 gausses and demagnetizing force is 1,820.—Indiana Steel Products Co., Valparaiso, Ind.

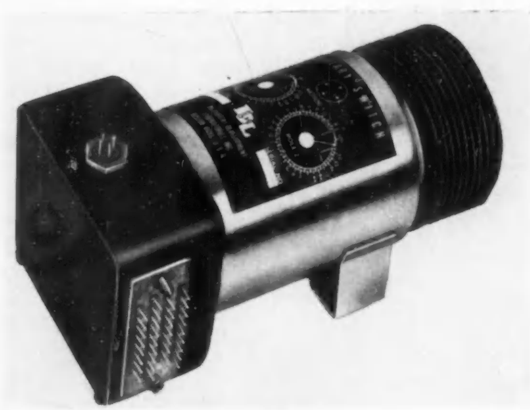
Circle No. 2 on reply card

LITTLE "TRAMP" features rugged design.

Weighing only 6 oz, this compact TRAMP (transistorized servo amplifier) is designed primarily to receive control transformer signals and to operate a size-15, 60-cps, 6.1-watt servo motor or equivalent. The unit mounts on four 6-32 weld studs. Standard model uses seven-pin plug-in connectors, but turret head terminals are also available.

On the electrical side, input impedance is 10,000 ohms, nominal. A typical voltage gain would be 550 volts at 2 watts output. Internal adjustments provide essentially 90-deg phase shift. Input power requirements are 28 vdc at 350 ma for maximum output, and 20 ma for zero signal.—M. Ten Bosch, Inc., Pleasantville, N. Y.

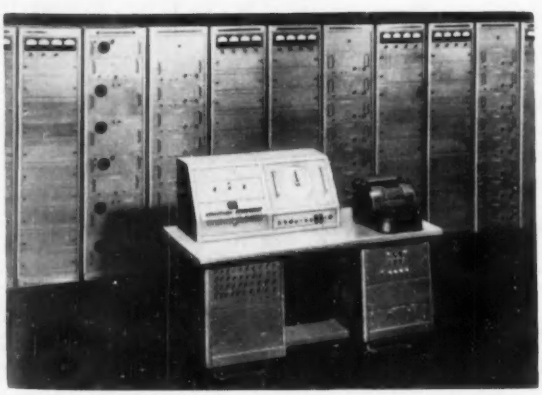
Circle No. 3 on reply card



NEW COMMUTATOR needs little power.

Powered by a 400-cycle, 115-volt, two-phase motor, this new telemetering commutator requires only 7 watts to provide 10-rps pole speeds, and only 15 watts for 30 rps. Brushes, or poles, are of special metallic alloys, dynamically balanced and mounted on jewel pivoted bearings with low spring rates. The commutating surfaces are made up of internally segmented cylindrical sections. Before assembly these sections are precision slotted to permit inter-pole phasing accuracies of 0.2 millisec at 30-rps pole speeds. Only 2½ in. in diam by 5¾ in. in length, the unit has exceeded 1,000 hours life at 10 rps and has withstood 2,000 cps vibration frequencies at 16-g amplitude.—Instrument Development Laboratories, Inc., Attleboro, Mass.

Circle No. 4 on reply card



TEST SET handles 1,000 components.

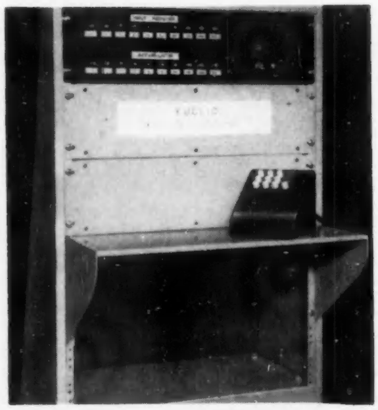
Called the Model 815 Life Test Set, the system shown here permits fast, accurate mass life testing of vacuum tubes, transistors, and other electronic components. Tests are performed simultaneously on up to 1,000 components.

The unit is said to provide an automatically commanded digital readout of operating information, in both visual and typewritten form. Readouts are made in sequence.

Flexibility is achieved by a logical breakdown of the equipment into 10 specimen racks, five power supply racks, and a control console. An initial installation for 200 components may be increased in multiples of 200 as need arises.—Systems Development, Inc., Binghamton, N. Y.

Circle No. 5 on reply card

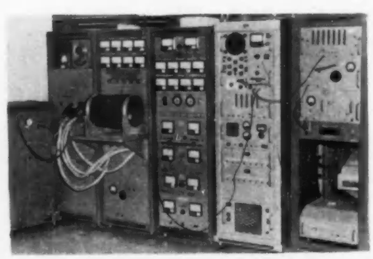
RESEARCH, TEST & DEVELOPMENT



SOLID STATE COMPUTER

One of the exhibits at the Automation Show in New York City was the "Euclid" solid-state computer shown above. This particular model performs decimal-to-binary conversion, and addition of binary numbers. Multiplication and division are accomplished by repeated shifting of digits and addition and subtracting. Numbers are handled within the computer in serial form; i.e., all digits of a number are transmitted over a single wire in a time sequence. Stepping rate of the binary digits is 20,000 per sec. Logic decisions and storage are accomplished in square hysteresis loop magnetic core circuits. Neon lamps are used only as indicators.—Stromberg-Carlson Div. of General Dynamics Corp., Rochester, N. Y.

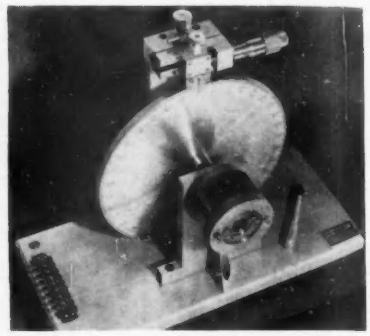
Circle No. 6 on reply card



PROGRAMMED TEST SET

The equipment above performs the complete final electrical test of a 177-channel FM/FM missile telemetering system in less than one hour. The semi-automatic set was designed to fill a need for a rapid and accurate check of telemetering packages without highly skilled technical people. One operator initiates the sequence of measurements. Setup includes: a power-supply rack to furnish the necessary voltages; a signal simulator rack to provide signals comparable to those of the missile's transducers; a read-out rack for analog-to-digital conversion; a sub-carrier analyzer rack to break down complex or mixed information; and a programmer rack that directs the sequence of operations and commands the printer to print.—Pacific Div., Bendix Aviation Corp., North Hollywood, Calif.

Circle No. 7 on reply card



ROTARY TESTER

A new addition to this company's line of test instruments, the rotary test gear shown here, permits rapid and accurate indexing of shaft position on rotary components such as potentiometers, resolvers, and synchros. Fixture consists of a precision gear fixed to a shaft and chuck. Millitest Co., Hempstead, N. Y.

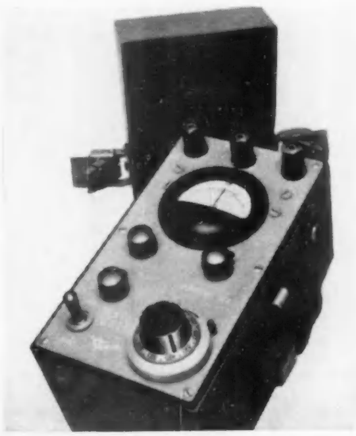
Circle No. 8 on reply card

NEW PHOTOMETER

This Universal Photomultiplier Photometer features high sensitivity and accuracy, low drift, flexibility of operation, and modest cost. Incorporating

a highly-regulated electronic power supply, the instrument uses no batteries, and is completely self-contained and portable. Unit provides separate zero and dark-current adjustments as well as both decade and continuously variable sensitivity controls. Provisions are also made for oscilloscope and graphic recorder readout.—Eldorado Electronics Co., Oakland, Calif.

Circle No. 9 on reply card



RATIO TESTER

The Model 11 Ratio Tester (above) measures dc voltage ratios in the range of 0 to 100 percent on instruments for aircraft and missile telemetering and measuring systems. Featuring its own mercury cells and standard cell, the unit provides voltages in two ranges: 1 volt and 10 volts. A switching arrangement permits use of either this internal source or an external source. The standard cell and precision components make the Model 11 an extremely accurate and versatile testing tool.—Allegany Instrument Co., Inc., Cumberland, Md.

Circle No. 10 on reply card

SUB-SYSTEMS

PACKAGED PROTECTION

A series of packaged protective and measuring systems is now available for pipe lines, chemical processes, and test facilities. These systems include plug-in electronic units for temperature, pressure, and vibration protec-

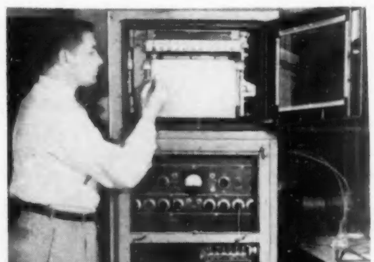
tion, pressure measurement, and telemetering. Plug-in construction permits the maximum compatibility between system and process. The system is designed so that only low-level sensing elements are located in hazardous areas. Cable connections are used throughout; no tubing is required.—Indikon Co., Watertown, Mass.

Circle No. 11 on reply card

POSITIONING SYSTEM

Pictured here is a new remote positioning system for transmitting motion with appropriate output power. It consists of three basic components: transmitter, amplifier, and receiver. Any form of motion, either linear or rotary, can be transmitted or received. Applications include fuel mixing and throttle control on engine test cells, valve operation in process work, and remote manipulation in radioactive or hazardous locations. The system also has a number of airborne applications. —The Bristol Co., Waterbury, Mass.

Circle No. 12 on reply card

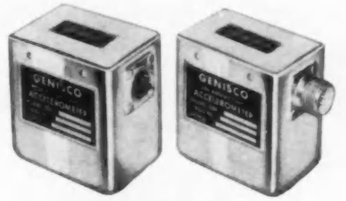


ON-STREAM ANALYSIS

Shown is Beckman's new process gas chromatograph which analyzes industrial gases by directly sampling a process stream. Samples are passed through a chromatograph column of absorbent material. This breaks them up into their component parts. A stream of helium washes the fractions out of the

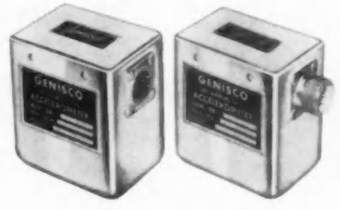
Model GLH

A rugged magnetically damped instrument with low natural frequencies for low range. High-quantity production assures good price and delivery schedules. Available in ranges from ±1 G to ±30 G.



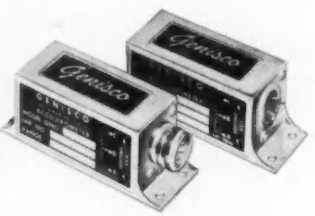
Model DDL

Magnetically damped low-range instrument available in ranges from ±1 G to ±30 G. Ultra-sensitive models supplied as low as ±0.1 G. Certified to MIL-E-5400 and MIL-E-5272A. Especially good in severe shock and vibration applications. An acceleration-sensitive switch version of the DDL is designated as the Model DDS.



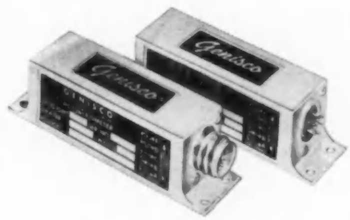
Model GAL

Incorporates a variable transformer a-c output with the magnetically damped sensory mechanism of the proven Models DDL and GLH. Superior reliability, life, resolution, and sensitivity. Available in ranges from ±1 G to ±30 G. Range as low as ±0.1 G also obtainable.



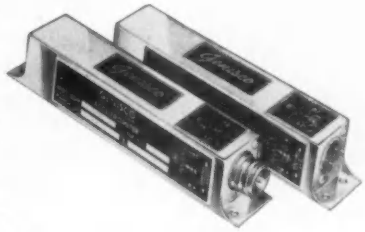
Model GMO

A rugged, miniature, viscous-damped instrument with ranges from ±2 G to ±30 G. Unbalanced-range instruments also available. Medium high natural frequencies.



Model GMT

Basically a Model GMO with internal thermostat-operated heater, assuring maximum environmental stability within the instrument. Damping remains constant with change in ambient temperature.



Model GDM

Miniature double-potentiometer instrument capable of sensing lateral acceleration in two mutually perpendicular planes (e.g., pitch and yaw). Ideally suited for missile and high-speed aircraft flight control systems.

NEW!

NEW! GENISCO ACCELEROMETERS NOW GOLD PLATED FOR GREATER RELIABILITY

CASES GOLD PLATED INSIDE AND OUT—This new trend in instrument plating has two important advantages over tin plating or fusing. Being the least active metal, gold prevents the formation of crystalline "whiskers" inside the case which could reduce performance and even cause malfunction. Gold plating also assures positive protection against corrosion to the exterior of the case and, because of its excellent solderability, makes possible a more reliable hermetic seal. The new gold plating is available on *all* models at *no extra cost.*

Descriptive data sheets available on all models. Please send request on company letterhead.

Genisco INCORPORATED

2233 Federal Avenue
Los Angeles 64, California

column in successive order and through a thermal conductivity cell that determines both the amount and type of compounds present. These data are presented as bar graphs on the recorder paper. Timed sampling valves can be set to analyze up to eight components of a single plant stream, or from two to seven different streams of similar composition. Once set, the instrument's operation is completely automatic.—Beckman Instruments, Inc., Fullerton, Calif.

Circle No. 13 on reply card

COMPACT EDGE GUIDE

More compact than earlier models, this new edge-guide unit is designed for light duty service in the rubber, plastics, textile, and paper converting fields. A self-contained regulator, motor, pump, and oil supply simplify installation of the unit.—Askania Regulator Co., Chicago, Ill.

Circle No. 14 on reply card

TAPE DUPLICATOR

A high-speed paper tape regeneration unit, consisting of a motorized tape reader cable-connected to a motorized tape punch, will duplicate 5-, 6-, 7-, or 8-channel tape at a rate of 1,200 codes per minute and produce a composite tape if required. The com-

NOW-PORTABLE 400 cycle power

This new frequency changer makes it possible to provide well regulated 400 cycle power conveniently and quickly. This unit, Model FCR 250, is extremely useful in a wide variety of applications including testing, production, airborne frequency control, computers, missile guidance system testing, and in practically any application where the use of 400 cycle power is advantageous.

Model FCR 250 is only one of a complete line of frequency changers available from Sorensen . . . the authority on controlled power for research and industry. Write for complete information.

ELECTRICAL CHARACTERISTICS

Input	105-125 VAC, 1 phase, 50-65 cycles
Output voltage	115 VAC, adjustable 105-125V
Output Frequency	320-1000 cps in two ranges
Voltage regulation	±1%
Frequency regulation	±1% (±0.01% with auxiliary frequency standard fixed at 400 cycles)
Load range	0-250 VA

MODEL FCR 250

SORENSEN & COMPANY, INC. Sorensen STAMFORD · CONN.

In Europe, contact Sorensen-Ardag, Eichstrasse 29, Zurich, Switzerland, for all products including 50 cycle, 220 volt equipment.

posite can then be used for wire-transmission, computer input, tape-to-card converters, recording instruments, and other equipment where one long tape accelerates data processing.—Commercial Controls Corp., Rochester, N. Y.

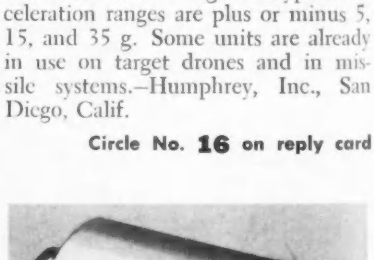
Circle No. 15 on reply card

MEASUREMENT & DATA TRANSMISSION

3-OZ ACCELEROMETER

This tiny (3-oz.) accelerometer is designed for use in instrumentation and control systems. Simple and rugged, the unit has a high output potentiometer pick-off and a pressure-sealed case. Operating temperatures range from minus 50 to 100 deg C. Typical acceleration ranges are plus or minus 5, 15, and 35 g. Some units are already in use on target drones and in missile systems.—Humphrey, Inc., San Diego, Calif.

Circle No. 16 on reply card

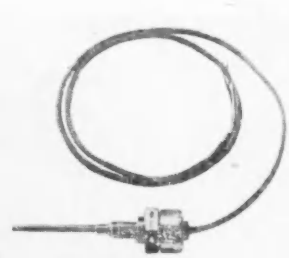


PRESSURE TRANSDUCER

A magnetic reluctance pressure transducer of the diaphragm type is now available in full-scale ranges from 1,000 to 10,000 psi. The unit operates in recording and control systems compati-

ble with inductance-ratio input devices, and permits static and dynamic pressure measurements accurate to within plus or minus 1 percent full scale. All surfaces exposed to the working fluid are 416 stainless, permitting direct use with corrosive liquids and gases. For extreme corrosion resistance an 18-8 type stainless modification can be built on special order. Unit weighs 18 oz, has a diameter of 1¾ in., and an overall length of 3⅝ in.—Pace Engineering Co., North Hollywood, Calif.

Circle No. 17 on reply card



PRECISION PICK-UP

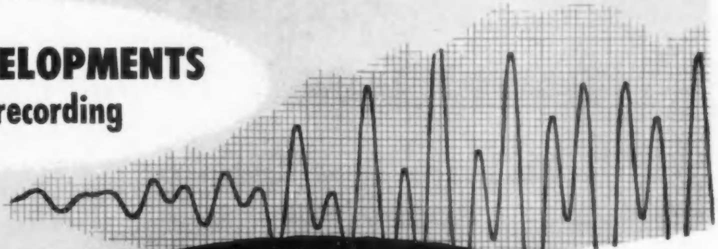
This series of resistance-bulb temperature pick-ups features high accuracy and wide range. The temperature interval over which the 100-ohm resistance change will occur may be as low as 100 deg F. Units have an output up to 5 volts without amplification. Available in various ranges from minus 300 to plus 1,800 deg F, the pick-ups are designed to withstand pressures up to 3,000 psia. When specified, they can be furnished for installation in corrosive liquids or gases.—Trans-Sonics, Inc., Lexington, Mass.

Circle No. 18 on reply card

SECTOR POTENTIOMETERS

Engineered for aircraft and missile control systems, these precision potentiometers are used for measuring angles from zero to a maximum of 90 deg of shaft rotation. Accuracy is

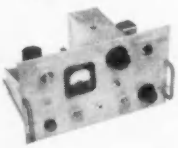
TECHNIQUES and DEVELOPMENTS
in oscillographic recording



FROM
SANBORN

PHASE SENSITIVE DEMODULATOR PREAMPLIFIER PROVIDES A DC VOLTAGE PROPORTIONAL TO AN INPHASE COMPONENT OF AN AC VOLTAGE WITH RESPECT TO A REFERENCE.

THE measurement of the amplitude of an AC voltage component is often necessary in performance studies of servo systems or of suppressed carrier signals over the carrier frequency range from 60 to 10,000 cps. In such cases the demodulator responds to inphase signals and rejects quadrature signals.

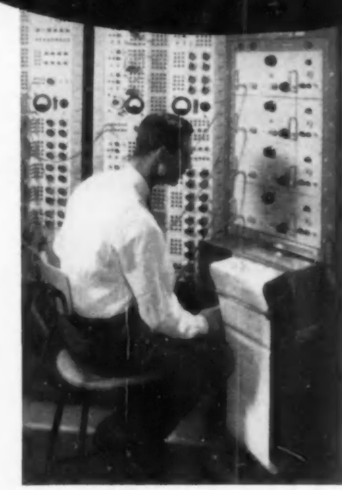


A circuit with these characteristics for use in an oscillographic recording system can be seen in the Model 150-1200 Servo Monitor (Demodulator) Preamplifier. It was developed by Sanborn as one of twelve interchangeable, plug-in front ends for "150" Series equipment, to be used with the appropriate Driver Amplifier-Power unit in any channel of a "150" system. Elements comprising the circuit from input to output, include: compensated stepped attenuator and cathode follower input circuit, phase inverter, push-pull mixer and demodulator stages, differential DC output amplifier and low pass filter. In addition, the chassis contains a VTVM to facilitate accurate adjustment of the reference voltage, and an overload indicator which lights a warning lamp when excessive quadrature voltages exist.

Adaptability to a fairly wide variety of applications is accomplished through broad input voltage, reference voltage and frequency ranges. In order, these are 50 mv to 50 v (for full scale 5 cm deflection), 10 v to 125 v; 60 cps to 10kc. Rise time with low frequency plug-in demodulation filter is 0.1 seconds; with high frequency filter, 0.01 seconds. Quadrature rejection is better than 100.1; for carrier frequencies up to 5000 cycles.

Two representative uses of the Servo Monitor Preamplifier are in the design and adjustment of servo systems, and with instruments used in the design, development or adjustment of other apparatus. The first is illustrated by use of the Preamplifier and associated equipment in the recording of the output shaft amplitude and driving frequency of an AC positional servo; the second by recordings made with a similar setup of the difference between output signals from a gyroscopically-controlled stabilizing device and the "pitch" and "roll" signals generated by a "Scorsby Table" used for testing the device under dynamic conditions.

For a detailed discussion of the principles and design considerations involved in the Servo Monitor Preamplifier, refer to the February, 1955 issue of the Sanborn RIGHT ANGLE, for Dr. Arthur Miller's article on "Measurements with the Servo Monitor Preamplifier."



BASIC FACTORS IN SELECTING OSCILLOGRAPHIC RECORDING EQUIPMENT

WHEN considering any oscillographic system or equipment for your application, three useful "yardsticks" to apply are (1) the recording method, (2) equipment adaptability, and (3) variety of equipment available. Here are the answers to the three, as they apply to Sanborn systems. In the record, rectangular coordinates accurately correlate multiple traces, simplify interpretation and eliminate errors. Permanent traces, produced by a hot ribbon stylus without ink, provide sharp peaks and notches, and clearly reveal all signal changes. One percent linearity results from current feedback driver amplifiers and high torque galvanometers of new design; maximum error is ¼ mm in middle 4 cm of chart, ½ mm across entire chart. From the standpoints of "adaptability" and "variety", Sanborn "150" equipment offers the versatility of 13 different plug-in front ends for any basic system . . . the choice of one- to eight-channel systems . . . the variety of nine chart speeds, timing and coding controls, console or individual unit packaging . . . availability of equipment as either complete systems or individual amplifier or recorder units.

The purpose of the foregoing information is to better acquaint industry with typical oscillographic recording problems and their answers, design considerations in Sanborn equipment, and basic data on what Sanborn makes and how it is being used.

Technical literature and engineering assistance on specific problems are always available from our engineering department.

SANBORN COMPANY
INDUSTRIAL DIVISION
175 WYMAN STREET, WALTHAM 54, MASS.

within 0.5 percent, resolution to within 0.10 deg. Units are rugged and well-insulated. They are particularly qualified for explosion-proof requirements, severe environmental conditions, vibration, shock, and temperature. The three available models come with shaft extensions from either or both sides, with terminals or integral cable, and singly or in dual gang units.—Humphrey, Inc., San Diego, Calif.

Circle No. 19 on reply card

FOR LOW FREQUENCIES

Slowly varying environmental phenomena from steady state to 40 cps can now be measured by this new series of differential transformer accelerometers. Based on a differential transformer transducer principle, these instruments feature high output with high resolution, no friction, and small size. The line includes units with ranges of from 1 to 10 g's, linearity within 1 percent, and sensitivities from 10 to 100 mv/g/volt input. Additional specs include hysteresis of less than 0.25 percent, output impedance of 1,900 ohms at 400 cps, and a weight of 3 oz.—Gulton Industries, Inc., Metuchen, N. J.

Circle No. 20 on reply card

LIGHTWEIGHT VENTURI

A new fabricated venturi tube, called type PVF, a departure from the standard cast-iron or plate-steel variety, is now available in sizes ranging from 6 in. to 96 in. in diam. An inner formed section (the venturi itself), stainless steel, eliminates the possibility of corrosion. The surrounding

NOW! LOW COST

MODULATING CONTROL

FOR TEMPERATURES UP TO 600° F

ANOTHER NEW IDEA FROM FULTON SYLPHON

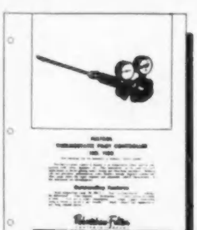
New FULTROL Thermostatic Pilot Controller No. 1100-C & D

Here is another example of how Fulton Sylphon gives you the best temperature control for your process at the lowest possible cost. This time it's an all-new FULTROL Thermostatic Pilot Controller—a simple, compact unit that now enables you to control temperatures up to 600° F. with *proportional* accuracy, but at *on-off* cost.

All that FULTROL needs is an air or other supply at a constant pressure anywhere between 18 and 40 psi. From then on, FULTROL strait-jackets temperature by modulating the output pressure to a final control valve, damper, or other device. FULTROL does all this by means of a simple, stainless steel thermal element. There are absolutely no troublesome pivots or levers.

What's more, you get all these extra features in the bargain:

- Instant knob adjustment of control setting over any 200° range specified between —50° F. and 600° F.
- Easily adjustable proportional band from 5° to 25° F.
- Protection against over-run temperatures (100° above range limit)
- Resistance to pressures up to 300 psi.



SEND TODAY FOR CATALOG SHEET NO. 10-28CW

Mr. Controls

Robertshaw-Fulton

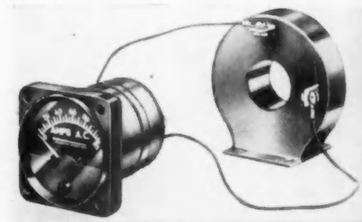
CONTROLS COMPANY

FULTON SYLPHON DIVISION • Knoxville 1, Tenn.

TEMPERATURE REGULATOR HEADQUARTERS, U. S. A.

and supporting section is constructed of stainless-clad or carbon-steel pipe. Single- or multiple-tap designs are available. The high pressure belt is made from a formed channel welded to the outside of the pipe. In a single tap tube, this is eliminated. The throat pressure belt is ordinarily formed by the space between the outside pipe and the insert. — Burgess-Manning Co., Philadelphia, Pa.

Circle No. 21 on reply card



LINEAR SCALE AMMETER

The linear scale ammeter shown here, developed for military use, has been successfully subjected to extreme vibration, shock, moisture, salt spray, and fungus over a wide range of conditions, from sea level to 50,000 ft, and from minus 55 to plus 71 deg C. The standard model is designed for use on a 200/115-volt three-phase, 400-cps system, but special models can be ordered. Unit is supplied with a special transformer for converting ac current to a 5-ma level. The transformer may be located 150 ft or more from the meter with no noticeable effect on accuracy.—Beckman/Helipot Corp., Newport Beach, Calif.

Circle No. 22 on reply card

POWER SUPPLIES

ULTRASONIC GENERATORS

A new series of ultrasonic generators, designed to drive a wide variety of low-impedance ultrasonic transducers, is now available. Accenting an untuned output system and featuring 500-watt RF power output plus a varied range of frequency levels, these generators should prove useful in many electromechanical techniques. Blower cooled, they operate at a

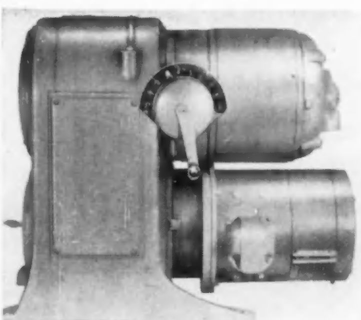
nominal fixed frequency of 40 kc or at any frequency between 20 kc and 2 mc.—Gulton Industries, Inc., Metuchen, N. J.

Circle No. 23 on reply card

AIRBORNE POWER SUPPLY

A transient-free, short-circuit-proof airborne power supply provides 22.5 vdc for various telemetering and instrument applications. An exclusive dual magnetic regulation frees it from line transients. One regulator, a high-performance flux oscillator, permits ultra-high speed control of line transients and line voltage changes; the other, a high-gain magnetic amplifier, regulates against load change. Result is smooth, filtered dc output with excellent static and dynamic regulation. —Magnetic Research Corp., El Segundo, Calif.

Circle No. 24 on reply card



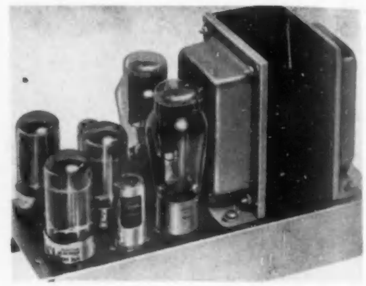
COMPACT POWER

Designed with the drive motor and alternator on the same side, a new line of Varidyne power units should prove extremely useful in applications where limited space is an important factor. A valuable characteristic of all Varidyne units is that all motors operating in tandem, as on a conveyor, carry an equal percentage of the load.

NEW PRODUCTS

This insures against costly damage from extreme overload at any one point.—U. S. Electrical Motors, Inc., Los Angeles, Calif.

Circle No. 25 on reply card

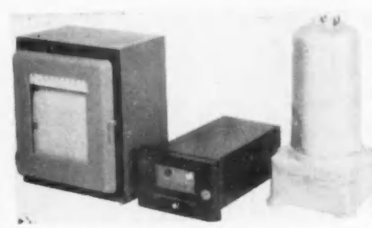


REGULATED DC POWER

This regulated dc power supply may be adjusted to provide any voltage between 300 and 500 vdc. Maximum output is 500 vdc at 300 ma. Unit also supplies 6.3-vac filament voltage at 6 amps max. A line voltage of 105 to 125 vac is regulated by a 0.5-percent change in the output voltage. Ripple is said to be below 10 mv rms for any voltage or load within ratings. The compact unit weighs only 23 lb. —Dressen-Barnes Corp., Pasadena, Calif.

Circle No. 26 on reply card

INFORMATION DISPLAY INSTRUMENTS

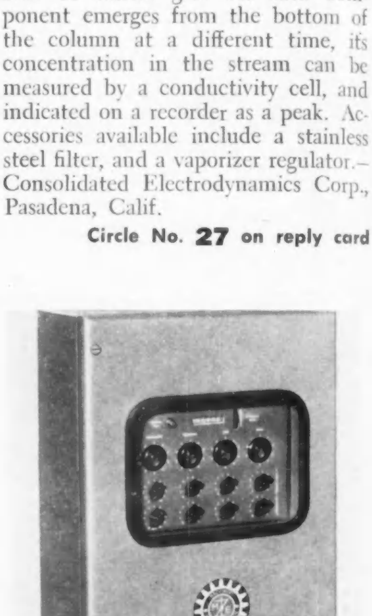


RUGGED CHROMATOGRAPH

Another instrument designed for vapor-phase chromatography, the Type 26-202 Process Chromatograph is said to be rugged, reliable, and easy to service. It consists of two units: the analyzer, built for use at the sample point or other hazardous locations in the plant; and the control unit, which may be located as much as

500 ft away. The instrument makes use of the elution method of vapor-phase chromatography. A fixed sample of gas is introduced into a carrier gas steam (e.g., helium, hydrogen, nitrogen), and washed down through a column by the continuous flow of carrier gas. As each component emerges from the bottom of the column at a different time, its concentration in the stream can be measured by a conductivity cell, and indicated on a recorder as a peak. Accessories available include a stainless steel filter, and a vaporizer regulator.—Consolidated Electrodynamics Corp., Pasadena, Calif.

Circle No. 27 on reply card



PRESET COUNTER

Designed for industrial applications, the MEK-2094-AG electronic counter will count dependably from 0 to 5,000 counts per second without special adjustments or circuit changes. Extremely flexible, the unit can operate with photoelectric, semiconductor, magnetic, or contact making pickups. At the end of the warning and final count plug-in relays are energized for control purposes. Warning circuits can be used to slow down the process to assure accurate control or to provide notice that the preset number is about to be reached. Several types of reset are available in the same unit. —Machinery Electrification, Inc., Northboro, Mass.

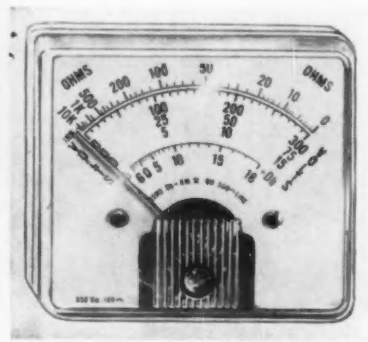
Circle No. 28 on reply card

PYROMETER CONTROLLER

A new multi-point pyrometer controller permits automatic temperature control of from four to ten separate

units with one instrument. It has the accuracy of a null balance potentiometer measuring circuit and the speed of an electronic control system. Unit applies to almost any installation requiring two-position control action. Such applications include creep test machines, multi-zone ovens and furnaces, aging and reaction vessels, batch process units, etc. A pulse timer and selector switch automatically connect thermocouples in sequence to the master control unit which compares each thermocouple voltage to its set point, and energizes or deenergizes the corresponding load relay.—Thermo Electric Co., Saddle Brook, N. J.

Circle No. 29 on reply card



PANEL METERS

Clear plastic cases aid illumination of the dials on these new panel meters. Case sizes and mounting provisions conform to acceptable industry standards. Stock models, all of which use D'Arsonval-type movements, include dc microammeters, milliammeters, ammeters, millivoltmeters, voltmeters, and similar ac types.—Waters Mfg. Co., South Sudbury, Mass.

Circle No. 30 on reply card

CONTROL DEVICES

PRESSURE SWITCHES

A new line of pressure switches specifically designed for aircraft use has just been added to this company's line of pneumatically actuated electrical devices. They may be used wherever electrical circuits must be switched in response to pressure changes in gases, liquids, and atmos-

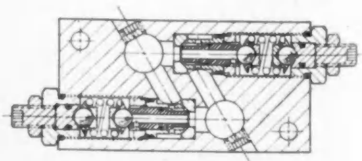
phere. Units will perform accurately in any position and will withstand the environmental requirements of appropriate MIL specs. Two sizes are available: regular, for pressures between 5 psi and 150 psi; and miniature for pressures from 2 psi to 100 psi, each in absolute, gage, or differential as specified.—The Bristol Co., Waterbury, Mass.

Circle No. 31 on reply card

DUAL-RANGE CONTROLLERS

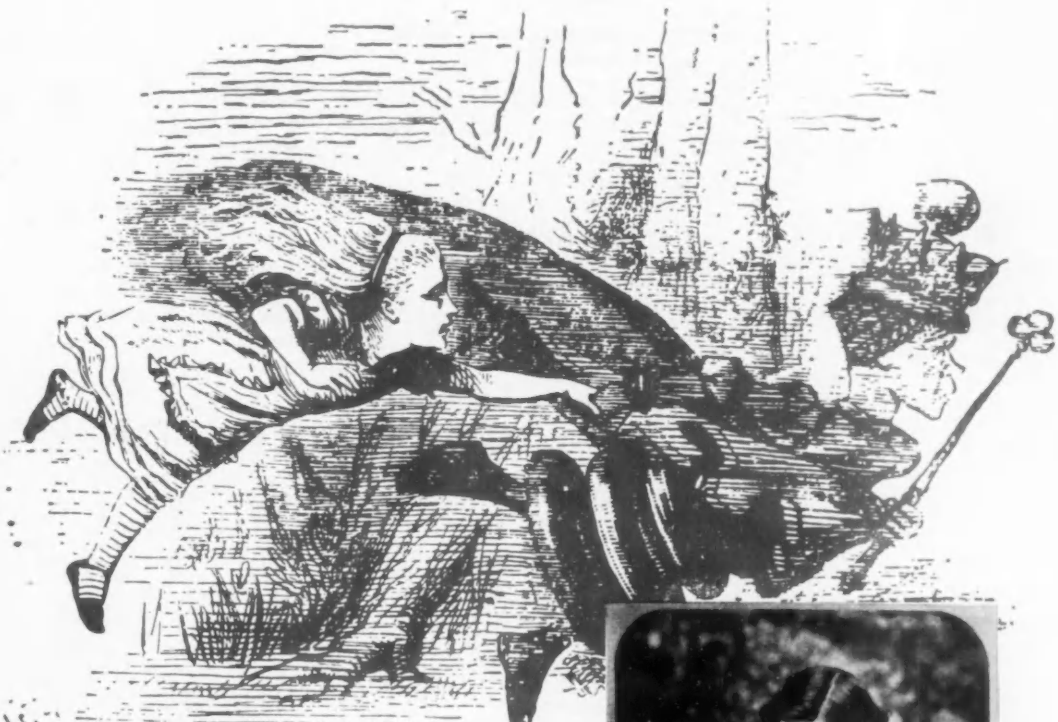
Two new dual-range thermistor-actuated temperature controllers are said to appreciably extend controller operating range. The operating ranges of Model 56006 are 200-600 deg F and 100-300 deg F, providing a total coverage of 100 to 600 deg F. Model 56007 covers minus 100 to plus 50 deg F, and 0-150 deg F, providing a total spread of minus 100 to plus 150 deg F. Ranges can be switched instantly without recalibration or other adjustments. This is done by positioning a selector switch on the front panel.—Fenwal Inc., Ashland, Mass.

Circle No. 32 on reply card



DUAL RELIEF VALVE

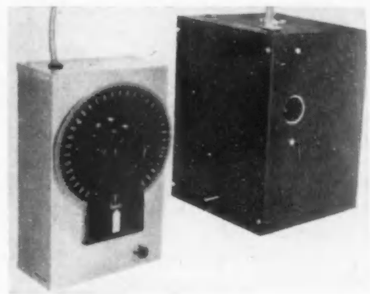
Shown is a cross-section of a new hydraulic relief valve designed to relieve shock pressures at control valves or motors. Available in either guided piston or differential piston types,



NEW PRODUCTS

these units protect hydraulic components and systems from excessive pressures when control valves are suddenly reversed or blocked or when an external load is applied to a motor. They also assure smooth, safe starting and deceleration of heavy loads. Units consist of two adjustable relief valves in one body. Each relieves in one direction, and can be adjusted to the same or different pressures. When pressure exceeds a desired setting, oil is relieved from one line and directed into the other line, thereby eliminating the necessity for a connection to the system reservoir.—Fluid Controls Inc., Mentor, Ohio.

Circle No. 33 on reply card



POSITION CONTROL

This new device provides automatic positioning control for a wide variety of industrial applications. Employing an unusual arrangement of bridge circuitry it positions to an accuracy of 0.5 percent and repeats to within 0.25 percent, without the use of vacuum tubes or photocells. One commercial use of this control is on a conveyor operating at 100 fpm. — Wallson Associates, Ltd., Newark, N. J.

Circle No. 34 on reply card

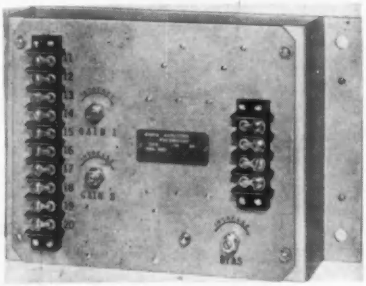
THERMAL TIME DELAY

This new thermal time-delay relay (overall length less than 2 in., diameter $\frac{3}{4}$ in.) features a contact rating of

3 amps at either 115 vac noninductive or 28 vdc noninductive. Unit operates in ambient temperatures from minus 65 to plus 125 deg C, and timing ranges run from 3 to 120 sec, plus or minus 10 percent. A port permits adjustments without removing the metal dust cover. Relay operates on a 2.5-to-115-volt ac or dc supply. Heater power is stated as 3.75 watts.—Belltron Mfg. Co., Bloomfield, N. J.

Circle No. 35 on reply card

FINAL CONTROL ELEMENTS



VALVE-AMPLIFIER TEAM

Billed as a team by Honeywell, this transistorized servo amplifier and a new electrohydraulic servo valve provide the building blocks for a variety of machine control systems. The all-transistor amplifier permits parallel summation, ratio comparison, or series summation of input signals. Designed primarily to supply power for this and other electrohydraulic servo valves, the amplifier may also be used to drive dc relays and dc servo motors. The valve is available with or without a linear variable differential transformer, depending on requirements. These rugged, precision-machined units were specifically designed for industrial applications. All are available now in limited quantities as pre-production engineering models. — Minneapolis-Honeywell Regulator Co., Machine Controls Div., Minneapolis, Minn.

Circle No. 36 on reply card

MOTOR-AND-GEAR TRAIN

Only 2.8 inches long, a new motor-and-gear train combination has an output torque of 25 oz-in. at 1.7 rpm, unloaded. Rated for continuous duty at 115 volts, 60 cps, it uses a single-phase capacitor or two-phase servo motor, and has an operating temperature range of minus 55 to plus 97 deg C.—John Oster Mfg. Co., Avionic Div., Racine, Wis.

Circle No. 37 on reply card

NEW PRODUCTS

NO STEM PACKING

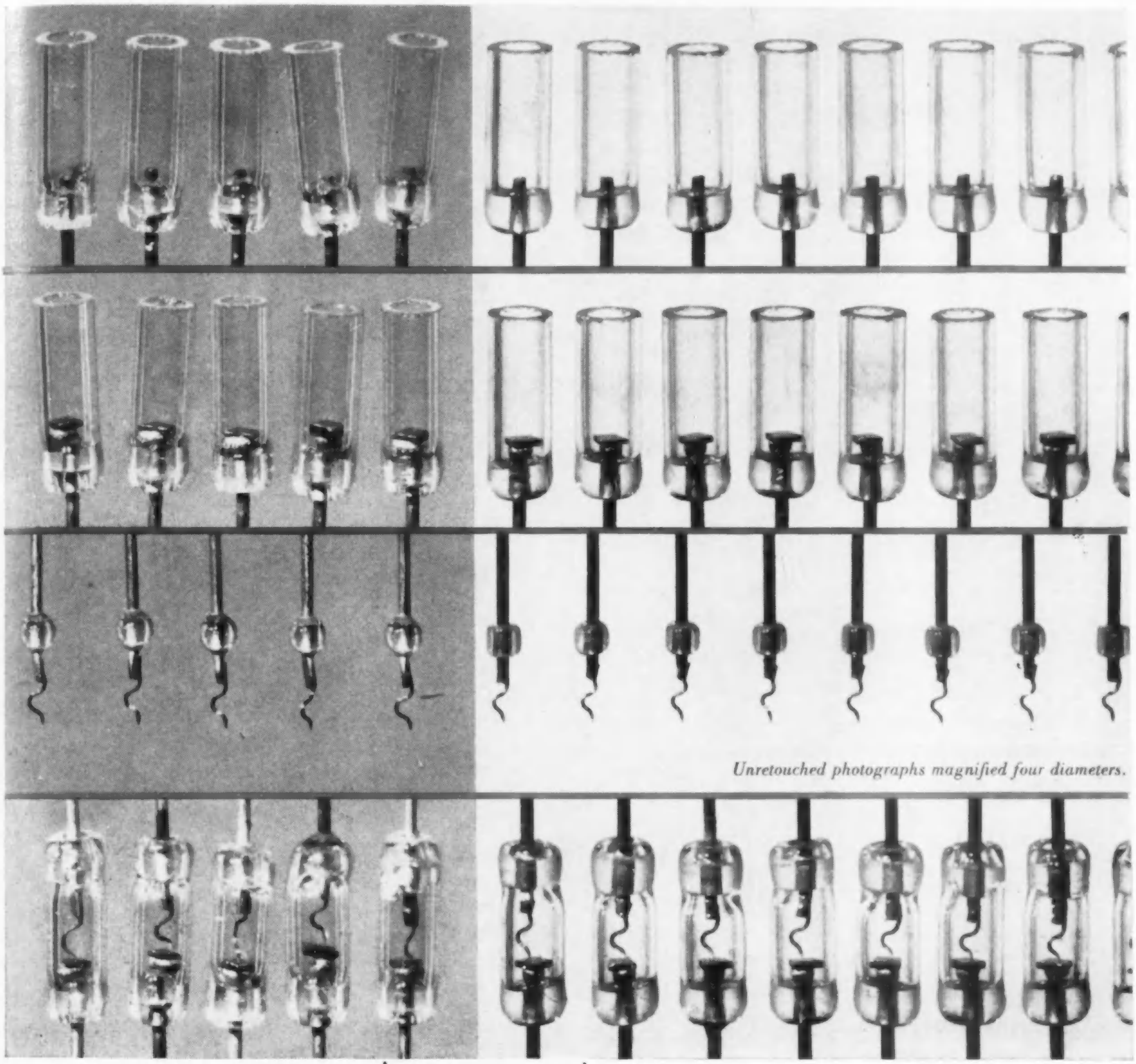
The springless, close-coupled control valve shown here is one of a complete new line of air operated valves for water treating, chemical, and process industries. Features include: no stem packing or stuffing box; tight shut-off; no clogging or sticking. Units are available with such optional features as handwheel-type limit stops, plastic position indicators, and microswitch attachments for actuating remote visible or audible signals. By means of a diaphragm closure, a positive drip-tight shut-off can be obtained.—Uniflow Valve Corp., Cranford, N. J.

Circle No. 38 on reply card

COMPONENT PARTS

DC-AC MAG AMP

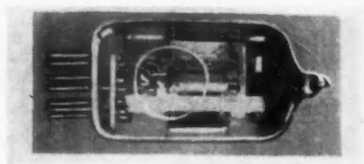
Designed for self-contained 400 cps input signals, this new magnetic



Hand assembled diodes ↑ COMPARE ↑ *Automatically assembled CBS diodes*

amplifier is adaptable to input signals from dc to 1,000 cps with the addition of a reference transformer. Unit requires no vacuum-tube or transistor driving stage in a normal servo loop. Potted and hermetically sealed, it is intended for use in instrument and computing servo systems. Circuit is of full-wave design. Coils and rectifiers are said to produce negligible temperature rise and provide reliable performance with a minimum of adjustment.—The Ahrendt Instrument Co., College Park, Md.

Circle No. 39 on reply card



SAVES COMPONENTS

Operating on the principle of ion deflection, the KP-80 coincidence thyratron (shown here actual size) may be used in circuits where the coincidence of two or three signals fires the tube. It should find wide application in computers, coding or programming devices, counters, or wherever else a coincidence function is to be performed. In circuits where these functions are now accomplished with as many as 14 components, this tube will save time, space, and money, and will increase equipment reliability.—Kip Electronics Corp., Stamford, Conn.

Circle No. 40 on reply card

ACCESSORIES & MATERIALS

SOLDER RESIST

A new solder resist developed for printed circuits permits selective soldering, reduces solder waste, and minimizes bridging over close tolerances. Certain areas of a printed circuit can be silk-screened to mask out solder "take" while others are soldered. About 20 to 30 min at 200 deg F are required for curing.—London Chemical Co., Inc., Melrose Park, Ill.

Circle No. 41 on reply card

LAMP EXTRACTOR

A handy device is now available for extracting and inserting switchboard lamps. About the size of a fountain pen, the new tool has a plastic chuck that slips over and firmly grips the lamp to be removed. It will fit into a pilot hole as small as 0.330 in. in diameter. When replacing, a new lamp is slipped into the chuck, seated, and released by means of a plunger.—Atocon Corp., Galion, O.

Circle No. 42 on reply card

RUGGED TEST JACK

An exclusive beryllium copper spring pin contact in this new test jack permits smooth insertion and withdrawal of standard 0.080-in. test prods. Contact assembly, silver plated with gold wash, provides low-contact resistance with the test prod, and fast, strong connection at the solder terminal. The mounting bushing is insulated from the contact assembly by a full-length nylon sleeve. For easy visual circuit identification, the nylon sleeves are available in nine different colors.—Raytheon Mfg. Co., Waltham, Mass.

Circle No. 43 on reply card

POCKET CALCULATOR

Problems involving frequency, inductance, and capacity are quickly solved on a new pocket calculator called the extended range Calculaid Frequency Computer. The device correlates, in one setting, the natural frequency and wave length of a circuit comprising a coil and condenser with the physical dimensions of the coil and the capacity of the condenser. Made of nonwarping vinylite plastic, the calculator measures 6¼ in. in diam.—American Hydromath Corp., Long Island City, N. Y.

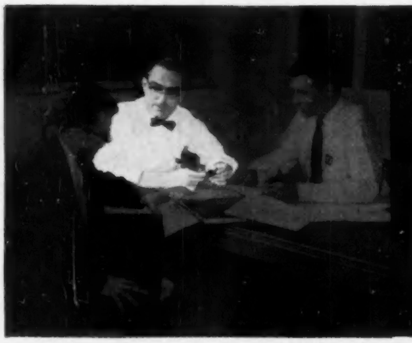
Circle No. 44 on reply card

Where do you belong in

Computer Circuit Design Engineers plan electronic circuitry for advanced airborne analog and digital computers . . . design linear and pulse circuits employing transistors, tubes, magnetic devices. Opportunities also exist in airborne power supply design, or to develop new techniques for marginally checking computer performance. *Do you belong on this team?*

Computer Logical Design Engineers determine the systems outline of a computer and its inter-connection with external equipment. Close liaison is maintained with mathematical support, circuit design, packaging and test engineers. Computer speed, memory size, configuration and arithmetic structure are tailored to requirements of weapons systems. *Do you belong on this team?*

Systems Evaluation Engineers test and evaluate electronic analog and transistorized digital computer systems design for aircraft; evaluate new systems and improvements to insure compliance with specifications and Air Force requirements. Other assignments: tie-in testing of peripheral equipment, liaison with design, development and field engineering. *Do you belong on this team?*



Harry Branning (center): B.S.E.E. 1950, Syracuse. Design Engineer in circuit design, 1951; October, 1954, promoted to Associate Engineer; April, 1956, promoted to Staff Engineer, Systems Planning. In June, 1956, appointed Project Engineer and Manager of the 110 Computer Circuit Design Department; discussing the performance and packaging details of a transistorized read amplifier.

William Dunn (standing): M.E. 1950, M.S.E.E. 1952, Stevens Institute. Technical Engineer, 1955; April, 1956, promoted to Associate Engineer; August, 1956, transferred to Development Engineering in charge of Logical Design for digital computers in advanced weapons systems; here discussing Boolean Algebra method of optimizing the logical design of an airborne digital computer.

Eli Wood (left): B.S.E.E. 1950, Connecticut. IBM Customer Engineer, July, 1950; September, 1952, transferred to ACL Field Engineering. February, 1954, in charge of Field Engineering at Hunter AFB; May, 1955, Associate Engineer; appointed Project Engineer, Manager of Systems Evaluation in August, 1956; here investigating a problem in radar data presentation set evaluation testing.

The brief records of the men cited above indicate only a few of the exciting activities right now in IBM Military Products. This division, organized 18 months ago, has grown enormously. A small-company atmosphere prevails. Men work in small teams . . . individual contributions are instantly recognized. Promotions occur frequently.

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ELECTRIC TYPEWRITERS
TIME EQUIPMENT
MILITARY PRODUCTS

IBM MILITARY PRODUCTS

IBM Military Products?

Systems Engineers oversee the engineering support provided by the Systems Coordination and Specification Group to the factory on the AN/ASB-4 Bombing-Navigational System. Air Force requirements are analyzed and the resulting engineering changes evaluated to determine effect on system performance and accuracy. Mathematical error analyses are run. *Do you belong on this team?*

Systems Analysts anticipate performance and recommend design criteria before and during development of equipment. Later, they compare dynamic performance accuracy and reliability characteristics with what has been anticipated. Other assignments include Digital Computer Systems Engineering, Input-Output and Analog-Digital Conversion Engineering. *Do you belong on this team?*

Quentin Marble (left): B.S.M.E. 1951, Syracuse. Joined IBM in 1951; promoted to Design Engineer in 1952; May, 1955, promoted to Associate Engineer, and then to Project Engineer, Manager of the Systems Coordination and Specification Group, Production Engineering Department, in February, 1956; shown here describing a unique cooling design to a new employee in his group.

Monroe Dickinson (left): B.S.E.E. 1952, W.P.I.; M.S.E.E. 1954, M.I.T. Technical Engineer in analog and alternate computer techniques for weapons systems, 1952; Associate Engineer responsible for systems design and analysis, 1954; December, 1955, Staff Engineer, responsible for research planning; here reviewing set-up on laboratory analog computer of a sampled data control problem.

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(100) COMBUSTION ANALYZER. Bailey Meter Co. Product Specification E65-5, 4 pp. Describes a new combustion analyzer which indicates percent by volume oxygen and combustibles present in exhaust gases from boilers and industrial furnaces. Provides operating and physical characteristics together with a list of accessories.

(101) ANNUNCIATOR SYSTEMS. Scan Instrument Corp. Catalog, 18 pp. Lists the manufacturer's complete line of self-policing, visual, and audible annunciator systems, tells what to consider when choosing an annunciator, shows wiring diagrams for alarm units, and gives other useful engineering and installation data.

(102) REMOTE POSITIONERS. The Jordan Co. Bulletin No. J-100, 8 pp. Covers electrical remote positioning controls for both pushbutton and automatic operation. Gives physical and electrical characteristics of each component and describes some typical applications.

(103) PYROMETER INDICATOR. Thermo Electric Co., Inc. Bulletin No. 64, 4 pp. Briefly describes a new portable pyrometer indicator, the MiniMite. Graphically illustrates several applications for this potentiometer-type instrument and points out some of its more important design features.

(104) RESEARCH AND TEST. Hathaway Instrument Div., Hamilton Watch Co. Catalog, 8 pp. This "short-form" catalog describes the more important items in this manufacturer's standard product line. A reference number corresponds to the complete catalog covering that particular type of equipment.

(105) AIRCRAFT SWITCHES. Micro-Switch Div., Minneapolis-Honeywell Regulator Co. Catalog 77, 24 pp. Covers 12 different families of precision, snap-acting aircraft switches. Complete with photos, dimensioned drawings, electrical ratings, and technical information, the catalog should make a handy reference for design engineers.

(106) TAPE RECORDING SYSTEMS. Consolidated Electrodynamics Corp. Bulletin 1561-B, 24 pp. Contains useful information on Consolidated's new magnetic tape recording and playback system. A block diagram, following a general description of the component parts, represents a typical airborne recording system. A few of the measured variables: stress, pressure, temperature, and vibration.

(107) FOR GAS ANALYSIS. The Hays Corp. Catalog 56-1008-59, 12 pp. Explains the principle of operation, construction, and special features of the company's thermal conductivity gas analyzer and electronic recorder, used for determining the amount of CO_2, H_2, He, CH_4, etc., present in a sample. Analyzing section, recording section, and gas sampling systems are covered separately.

(108) TUBE FITTINGS. The Weatherhead Co. Catalog, 48 pp. Incorporates complete engineering data on Weatherhead's 7000 and 8000 Series Ermeto hydraulic flareless tube fittings, and their SAE 37-deg flare hydraulic fittings.

(109) HEAVY DUTY SWITCHES. Micro-Switch Div., Minneapolis-Honeywell Regulator Co. Brochure, 8 pp. Discusses the advantages of using the manufacturer's heavy duty precision switches for machine tool control and other industrial applications. Covers six types, each with a variety of actuator designs.

(110) FLAT BELT CONVEYOR. Richardson Scale Co. Bulletin No. 0456, 4 pp. Describes a new adjustable length flat

belt bag conveyor for use with or without a bag closing machine. A dimensioned drawing permits a rough estimate of the space required for an installation.

(111) "TEFLON" PRODUCTS. Haveg Industries, Inc. Brochure T-50, 4 pp. Details the exceptional properties of "Teflon". Chemical, mechanical, thermal, and electrical properties are each covered in separate tables, with an additional table for other interesting properties.

(112) EDGE CONTROL. Interconti-nental Dynamics Corp. Bulletin No. IDC-8, 4 pp. Describes a complete system for the precise control of edge register of a moving material. A number of applications for four types of sensing heads are given, along with detailed specifications. Diagrams illustrate the operating principles.

(113) NEW INFRARED ANALYZER. Perkin-Elmer Corp. Brochure, 4pp. Outlines the features and specifications of Perkin-Elmer's Bichromator Analyzer, answering such questions as what is it?, where is it used?, and what is infrared? There is also a schematic diagram of the optical layout and basic design.

(114) FOR REACTOR CONTROL SYSTEMS. Minneapolis-Honeywell Regulator Co., Industrial Div. Specification S901-6, 4 pp. Lists a number of features found in the new Brown Log-N and Period Amplifier. A circuit diagram illustrates the convenient design, and a block diagram shows the location of the amplifier in a typical reactor control system.

(115) POTENTIOMETER PYROMETER. Technique Associates. Bulletin 9B, 8 pp. Covers the design and operation of the Pyrotest, a portable potentiometer pyrometer with interchangeable direct-reading scales. Includes a cutaway view showing the compact construction of the unit.

(116) DECADE RESISTANCE UNITS. Muirhead & Co. Ltd. Publication 1742-A, 2 pp. Describes a line of improved nonreactive resistance units that supersede the manufacturer's type A-5 Decade Resistance Units. Lists general specifications and then details the electrical and mechanical characteristics of each model.

(117) ELECTRIC MOTORS. Sterling Electric Motors, Inc. Condensed Catalog, 18 pp. Gives prices and selection data for the more common electric power drives. Covers normal speed electric motors, geared motors, variable speed transmissions, and speed reducers. Easy-to-read tables simplify drive selection.

(118) PROPELLANT VALVES. Hydromatics, Inc. Tech Bulletin 24, 4 pp. Illustrated brochure describes a complete series of high-pressure linked multi-line propellant valves for fuel-oxidizer flow control, discusses technical design features and includes photos and dimensions of typical models.

(119) INDUSTRIAL ELECTRONICS. Amphenol Electronics Corp. Catalog IEC-2, 16 pp. Lists the company's complete line of industrial electronic components, many of which are now available for same-day delivery from distributor's stock. Two-page chart shows AN insert contact arrangement for connectors with from 1 to 52 contacts.

(120) DUAL RELIEF VALVES. Fluid Controls, Inc. Catalog sheets No. 1.61 and 1.60a. Illustrates and describes Fluid Controls' new line of hydraulic dual relief valves. Includes schematic drawings of both guided-piston and differential-piston type valves.

(121) THREE-MINUTE SYNCHROS. Norden-Ketay Corp. Bulletin No. 409, 4 pp. Gives complete specifications of a new line of size 23 synchros with a maximum electrical error of 3 min. Eight models include four control transmitters and four control transformers. Mounting dimensions are also given.

(122) RUGGED SWITCHES. Donald P. Mossman, Inc. Catalog No. 200, 4 pp. Contains information on a variety of turn, pushbutton, and lever switches; gives instructions on what data to include when ordering from this manufacturer.

(123) FIXED COMPOSITION RESISTORS. International Resistance Co. Catalog Data Bulletin B-1A, 12 pp Contains comprehensive data on the construction, characteristics, solderability, heat dissipation, color coding, resistance values, and tolerances of the company's Type BT Fixed Composition Resistors.

(124) MOTOR SELECTOR. Reliance Electric & Engineering Co. Bulletin B-2103-1, 12 pp. Titled "Reliance Motor Selector", this bulletin gives full information on how to select proper ac motors for specific applications. Includes such data as speed-frequency relationship, NEMA design classes, torque characteristics, frame selection tables, and dimension charts.

(125) RECORDERS. Penn Instruments Div., Burgess-Manning Co. Brochure No. 1021. Describes the operation and advantages of the filled-tube system recorders. Also includes drawings and text on the friction-free pen movement, the rigid "girder" assembly of the instruments, and the "flooded-cup" pen design.

(126) TEMPERATURE REGULATORS. Atlas Valve Co. Bulletin TR-57, 4 pp. Covers a description of two self-contained, vapor-pressure-operated temperature regulators, and suggests applications for each. Data on installation, start-up, adjusting, and servicing are included.

(127) GENERAL STOCK CATALOG. Fischer & Porter Co. Catalog 2, 32 pp. Contains a general description of Fischer & Porter equipment that is available for immediate shipment. Sizing nomographs

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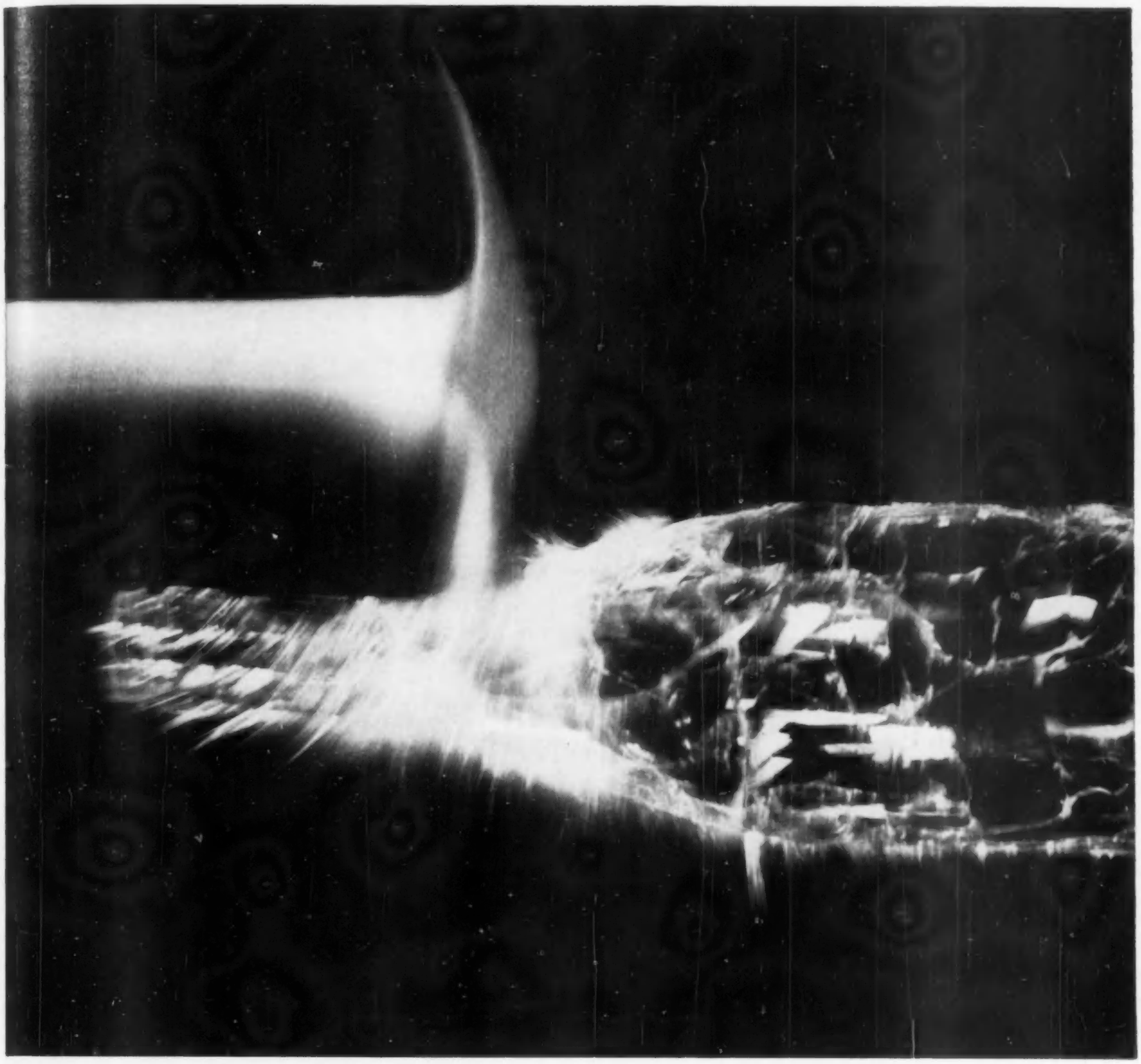

IMPACT

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for flowmeters and a pressure specifications chart supplied.

(128) FLEXIBLE HOSE & TUBING. American Metal Hose Div., The American Brass Co. Catalog G-560, 60 pp. Describes a wide variety of metal hoses and tubes for almost every conceivable application. Covers welded, soldered, and threaded fittings, with complete specifications on each type.

(129) RANDOM VOLTAGE. Intercontinental Dynamics Corp. Brochure on Model G-1000. Refers to a new random voltage or noise source with a precisely controlled power frequency spectrum and predetermined amplitude probability characteristics. Contains specifications, characteristic curves, and a block diagram.

(130) PRECISION POTS. Helipot Corp. Data Sheet 54-18 series B, 2 pp. Covers the improved operating characteristics of the company's new series B precision potentiometers. Illustrates the internal construction and contains dimensioned drawings. Also lists specifications of standard linear models, and standard linear coils.

(131) PACKLESS VALVES. George W. Dahl Co., Inc. Bulletin 1000, 6 pp. Illustrates a number of packless valves and manifolds featuring both tee and toggle actuators. Data on typical applications, construction features, flow capacities, and ordering instructions are included.

(132) ELECTRON MICROSCOPES. North American Philips Co., Inc. Catalog, 12 pp. Gives complete data on Norelco's electron microscopes. Well illustrated, it covers such things as the optical system, the pumping unit, and the accessory equipment. Also included are several typical photomicrographs.

(133) RESISTORS & RHEOSTATS. Hardwick-Hindle Inc. Stock Bulletin 53, 4 pp. Covers the manufacturer's line of vitreous enameled rheostats, fixed resistors, and variable resistors. Tables of sizes and ratings follow a general description of each.

(134) THERMOPILES. Hilger & Watts Ltd. Catalog CH-315/5, 12 pp. Describes the maker's air and vacuum thermopiles, listing the physical characteristics of each. Thermopile applications are suggested, and a description of the Hilger amplifying galvanometer system is given.

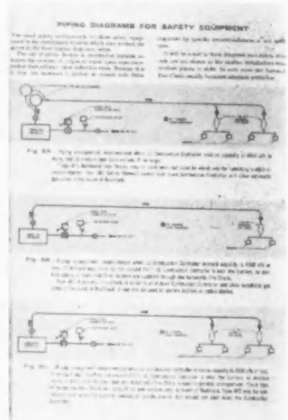
(135) COATED FABRICS. The Connecticut Hard Rubber Co. Bulletin F-56, 4 pp. Covers both silicone rubber and nylon resin coated fabrics. Discusses their properties, applications, and construction. Also describes silicone rubber compounds for different temperature ranges.

(136) DIGITAL EQUIPMENT. Computer Measurements Corp. Short Form Catalog 56-57, 12 pp. Illustrates the more important features of CMC's electronic counting, timing, and controlling instruments. Sectionalized layout enables anyone to readily determine the adaptability of the unit to a particular need.

(137) DIGITAL COMPUTER. Computer Div., Bendix Aviation Corp. Bulletin AB-116, 6 pp. Covers the highlights of the Bendix G-15D general-purpose digital computer and its digital differential analyzer accessory. Shows how the versatility and range of operations of the basic computer are considerably increased by this new accessory.

APPLICATION LITERATURE

(138) FLASHBACK PROTECTION. Selas Corp. of America. Bulletin SC-1006-Rev, 12 pp. This bulletin begins with a brief definition of the term "flashback" and a distinction between two stages of flashback control. It then describes the Selas Automatic Fire Check. Covers principles of operation, design and construction features, and installation techniques.


PIPING DIAGRAMS FOR SAFETY EQUIPMENT

One figure shows six positions in which these Fire Checks may be installed. Selection data include a graph showing the pressure drops for various rates of flow through five different size Fire Checks, and a table listing the dimensions of each model. Pages 7 to 11 cover the manufacturer's Safety Blowouts for containing damaging flashback. Figure 5, shown here, illustrates three typical piping arrangements using the equipment.

(139) VERSATILE GALVANOMETERS. Consolidated Electrodynamics Corp. Bulletin 1528, 12 pp. Covers Consolidated's 7-300 Series galvanometers. Completely self-contained, these sealed units convert an incoming electrical signal into a moving light beam. Principles of operation are discussed on page 4. An isometric drawing of a typical unit appears on page 5 (shown), along with a description of the more important construction features. Galvanometer characteristics, including frequency response, damping relationship, linearity, phase relationship, and square-wave response, are outlined, with a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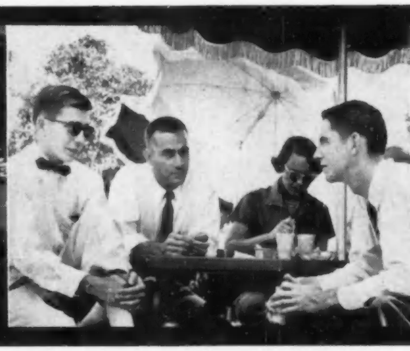
In development engineering laboratory, George M. Slocomb (center), 31, supervisor of digital data processing section, explains new test procedure in transistor circuitry for digital data handling. Viewing breadboard demonstration are engineers Bob Kelly (left) and Wayne Hodder. *CEC's substantial R&D budget is 2-3 times greater than normal budgets—totals 10-15% of sales.*



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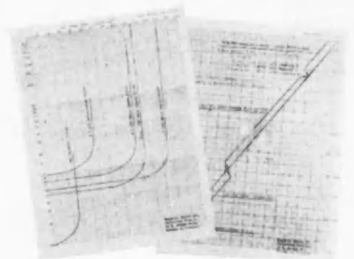
APPLICATION LITERATURE

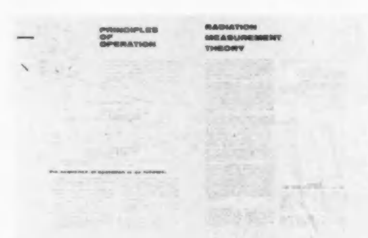
graph illustrating each. Page 9 shows application circuitry for using the units in strain gages, potentiometers, thermocouples, and other equipment. Bulletin also includes complete specifications and a section on selecting galvanometers.

(140) MAGNETIC SHIELDING. Magnetic Shield Div., Perfection Mica Co. Data Sheets 101 (1957), 33 pp. This technical brochure completely describes the construction features, performance characteristics, and typical applications of nonshock-sensitive, nonretentive Fernetic-



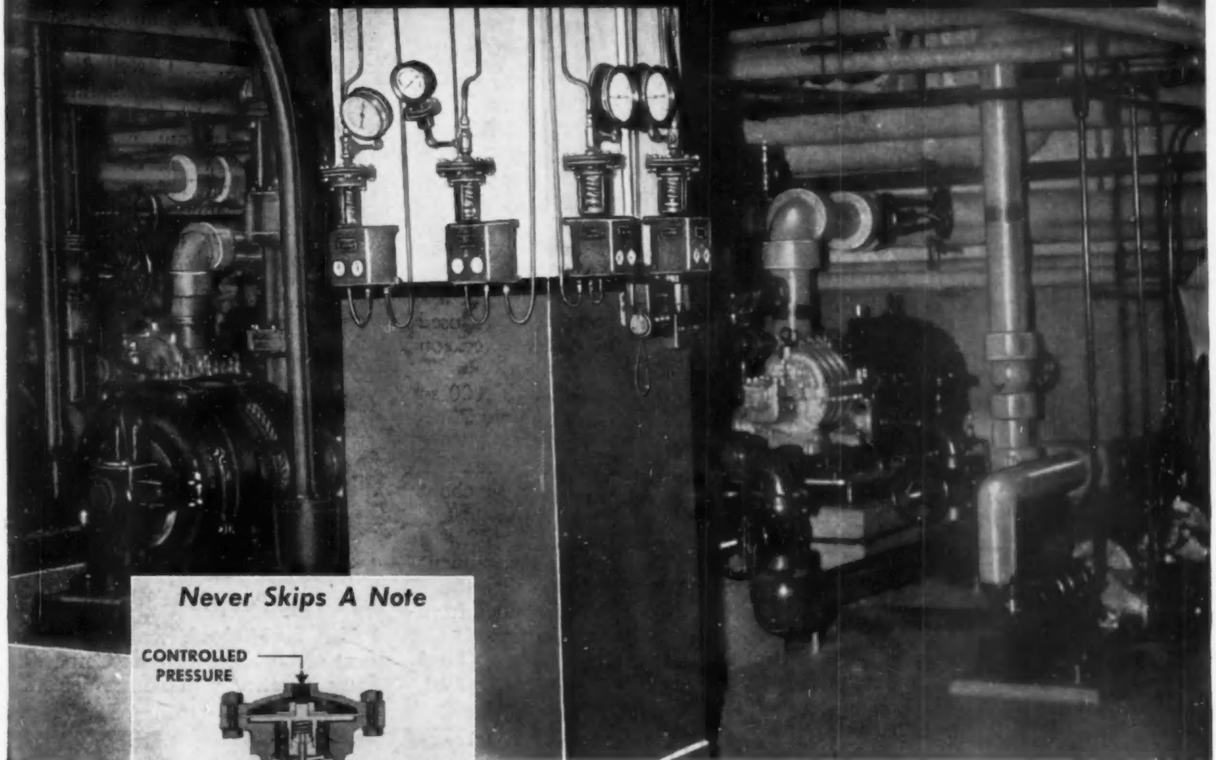
and Co-Netic magnetic shielding material. It includes 12 pages of technical data, five of performance graphs (two shown), 14 pages of illustrations, and a handy two-page comprehensive index. One typical example covered is the shielding of photomultiplier tubes used in scintillators. Such units, properly designed, can often be made smaller and more efficient simply by choosing the right shielding material. Brochure also candidly states several applications in which these materials cannot be used.

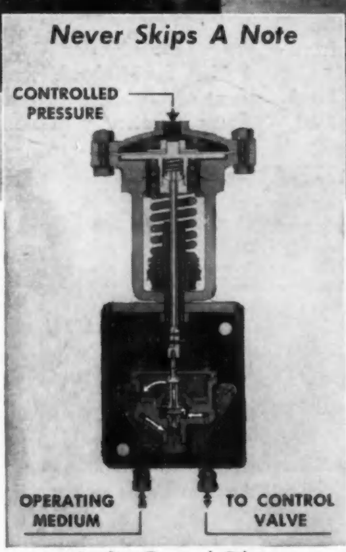
(141) "EVAPOGRAPH". Baird Associates-Atomic Instruments Co. Bulletin RD-515, 12 pp. The Evapograph, a direct thermal imaging device, is completely described in this bulletin. Dubbed "Eva" by its makers, this instrument can be used for locating and monitoring either hot or cold spots. Specific applications illustrated in this bulletin include insulation studies, and



testing bonds and laminations, process equipment such as heat exchangers and fractionating columns, and temperatures of electronic components in actual service. The two-page spread shown here illustrates the sections on "principles of operation" and "radiation measurement theory". Subsequent sections deal with various temperature measurement methods and the difference between photographic and visual techniques. Schematics, curves, and detail drawings are used throughout. Specifications of the standard unit are also included.

Here's a Quartet of Control Pilots that Sings a Song of Savings





Leslie Control Pilot
Type PDA
Sectional View

NEVER A DISCORDANT NOTE from this quartet - - - they're always in tune - - - each unit doing its part to create 24-hour-a-day harmony. They save time — no personal attention or manual assistance required after they're set. Pressures stay at set point for top efficiency of process equipment in the line. Positive response of pilot and valve assures smooth throttling action within closely held limits.

The same smooth action and accurate control is provided even when extreme reductions are necessary (there are Leslie installations handling reduction of 2150 psi. to 5 psi. in one step!) Responds to pressure deviations as small as .025 psi., depending on pilot range.

For more information on controllers that save maintenance dollars, consult the nearest Leslie Engineer listed in your classified telephone directory under "Valves" or "Regulators". Use this help for economy in temperature and pressure regulation.

Bulletin 5303 sings the whole song. Send for it today.

TRADE LESLIE MARK

REGULATORS AND CONTROLLERS

LESLIE CO. 211 GRANT AVENUE, LYNDHURST, NEW JERSEY

(*Continued from page 42*)

Systems Engineering Dept., is president, and George, formerly manager of military operations, is vice-president and treasurer.

Companies A-Building

▶ A new plant (30,000 sq ft) in Los Angeles, for **Gertsch Products, Inc.,** which has need for new facilities to handle its increasing orders for electronic instruments. Land around the new plant will permit even further expansion.

▶ An addition to its assembly plant in New Hyde Park, N. Y., for **Servo Corp. of America.** The new plant will increase by 50 percent the area used for assembling and testing precision electrochemical products.

▶ A manufacturing facility (81,000 sq ft) in Phoenix, Ariz., for **Sperry Phoenix Div.** of **Sperry Rand Corp.** The $3 million unit, expected to be completed next August, will employ about 500 persons.

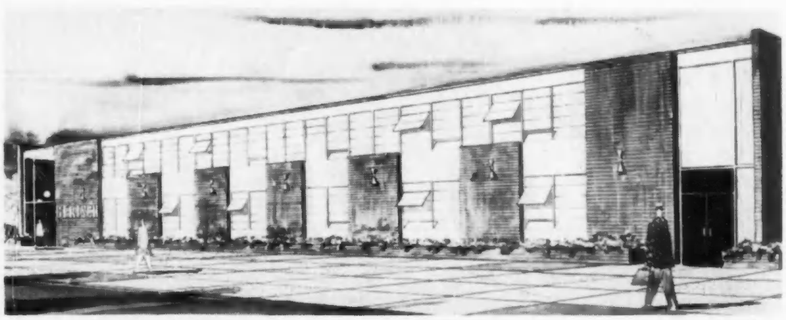
▶ A new home (128,000 sq ft) in Waltham Research & Development Park in Waltham, Mass., for **Sanborn Co.,** which completed its move from Cambridge, Mass., in December.

▶ Among recent acquisitions: **Ford Engineering Co., Inc.,** of Upland, Calif. (manufacturer of the Multipot potentiometer) by **Daystrom, Inc.,** which will carry Ford's President Alfred S. Voak as a consultant; **Watts Mfg. Co.** of Ronceverte, W. Va. (temperature test stands, automatic flaw detectors, and a continuous-action gas chromatograph) by **Beckman Instruments, Inc., R. A. Castell & Co.** of Glendale, Calif. (subminiature electronic components) by **Consolidated Electrodynamics Corp.,** which will operate Castell as a new **Glendale Div.; Dynamics Research Associates** of Seattle (the Dynamag magnetic amplifiers for airborne and industrial applications) by **Universal Match Corp.,** which has named DRA's Alfred C. Black and Robert G. Bryson general manager and assistant general manager, respectively, of its new **DRA Div.;** and **Lindsay Products, Inc.,** of Culver City, Calif. (miniature dc motors) by **The Cramer Controls Corp.,** which will run Lindsay as a new **Western Div.** under General Manager C. T. Scott.

▶ And a merger: **Midwestern Instruments, Inc.,** and **Magnecord, Inc.**

Important Moves By Key People

▶ **Hall L. Hibbard,** senior vice-president of Lockheed Aircraft Corp., who figured indirectly in a mass defection



Gertsch Products builds in Los Angeles: additional room for an expanding production.

More room for Servo Corp. on Long Island: assembly area increases by 50 percent.

from the Missile Systems Div. in December '55 (CtE, Feb. '56, p. 24)—he stood firm while 20 others walked out—has been succeeded as pro tem director of the division by **L. Eugene Root.** At the same time, **Herschel J. Brown,** acting general manager of the division, becomes permanent manager. Root's experience in industrial and governmental areas as an R&D man in aerodynamic design, air weapons research, and military systems and operational analysis is impressive: advisor to the AF Institute, lecturer at the Guggenheim Aeronautical Laboratory at Cal Tech, member of the Scientific Advisory Board to the AF Chief of Staff, consultant to the assistant secretary of defense for R&D, division chief of Rand Corp., and chief of the Aerodynamic Section of Douglas Aircraft at El Segundo, Calif. His elevation by Lockheed will put him in charge of a 5,000-man payroll in San Francisco.

▶ Recent personnel changes at Pratt & Whitney Co., Inc., saw **Jacob J. Jaeger** and **Albert L. Knapp,** both vice-presidents, elected to the board of directors, and **Harry Reichert,** export manager, raised to vice-president. Jaeger, a CtE *Control Personality* (Oct. 1956, p. 23), and Knapp are, besides V-P's, chief engineer of the Machinery Div. and manager of the Machinery Div., respectively. Jaeger came to the company in 1940, was named chief engineer in 1954 and V-P in 1955; Knapp, a 28-year man, became V-P in 1955; Reichert joined in 1925 and has been export manager since 1950.

▶ Overall responsibility for Minneapolis-Honeywell's activity in industrial controls goes to **Henry F. Dever,** who will coordinate operations of seven M-H divisions from headquarters at Philadelphia. He will continue as president of the company's Brown Instruments Div., although the division's daily operations will now be under the direction of General Manager **C. L. Peterson,** a V-P.

▶ Airborne Instruments Laboratory has established a new Research Div. and has put **Arthur V. Loughren** at its helm as vice-president. Loughren, a past-president of IRE and holder of several awards for his work in vacuum tubes, tuned r-f receivers, color TV, etc., comes to AIL from Hazeltine Corp., with which he had been associated for 20 years, most recently as vice-president for research.

▶ **Donald D. King,** formerly director of the Radiation Laboratory at Johns Hopkins University, joins Electronic Communications, Inc., as vice-president for research. As such, he will pilot studies in electronic countermeasures, systems, infrared applications, and other areas, at the new Research Laboratory of the Air Associates subsidiary in Baltimore. He will con-

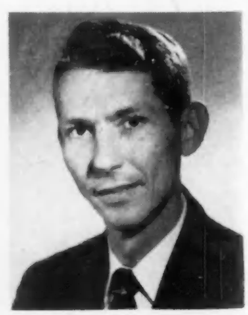
L. E. Root

J. J. Jaeger

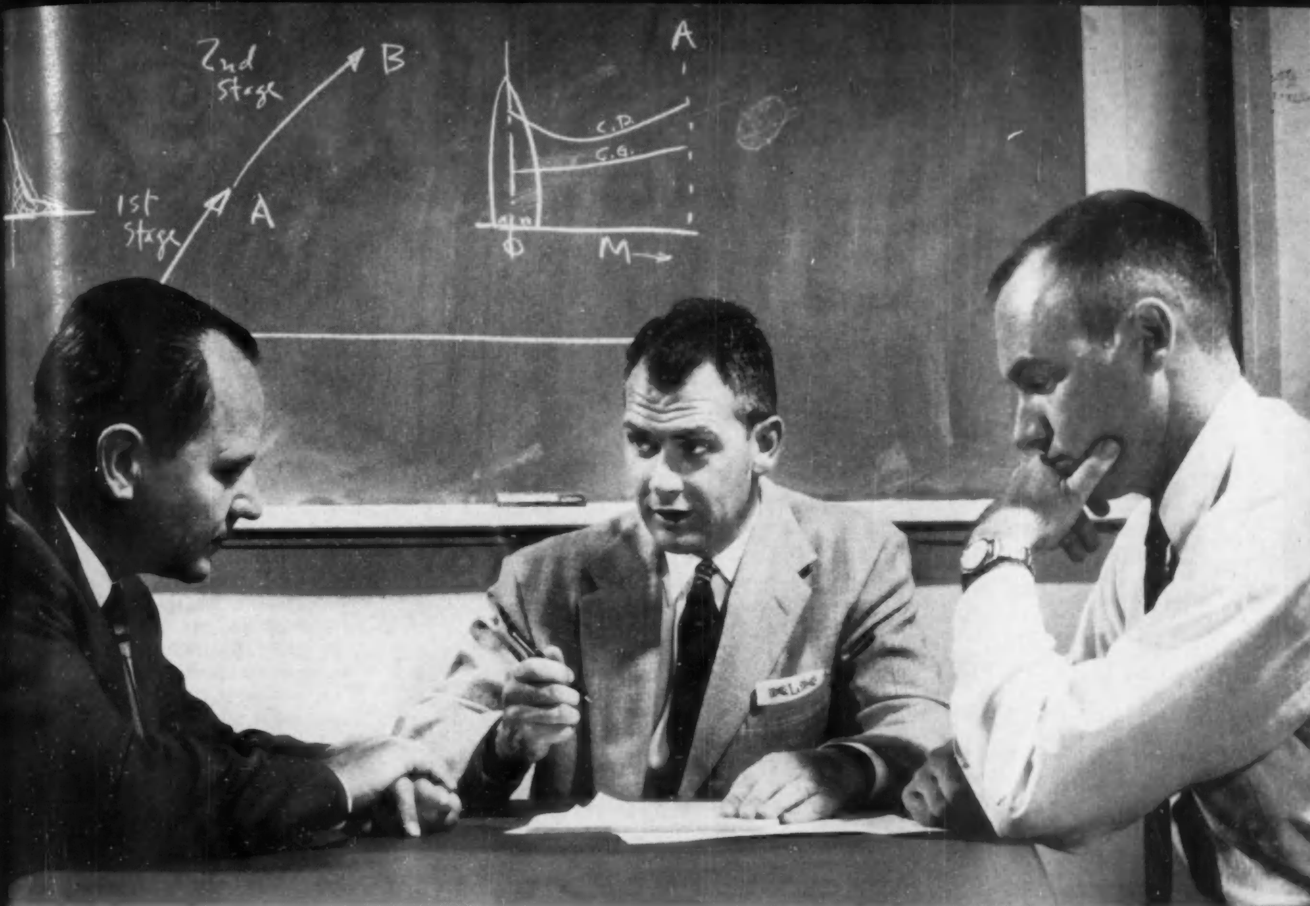
H. F. Dever

A. V. Loughren

D. D. King



Parker Painter Jr.



L. K. Edwards (center), advanced design and systems analysis department head, discusses launching of a ballistic missile with W. P. Gruner (left), head of weapons systems integration, and Systems Analyst G. W. Flynn.

the creative approach to MISSILE SYSTEMS ANALYSIS

There are few areas in which engineers and scientists can apply their abilities so broadly as in Lockheed's concept of systems analysis. Lockheed systems analysis staff members engage importantly in virtually every phase of missile preliminary design and development as they:

- formulate overall analytical treatment
- perform original analyses when problems defy conventional handling
- coordinate analytical activities among different departments

Because Lockheed is involved primarily in frontier activities, its systems analysis emphasis is on new approaches, new techniques, new ideas. It is work that calls for flexible, creative minds.

Inquiries are invited from engineers and scientists possessing those attributes. Positions are open at both Van Nuys and Sunnyvale, California, centers.

Lockheed

MISSILE SYSTEMS DIVISION

research and engineering staff

LOCKHEED AIRCRAFT CORPORATION

VAN NUYS • PALO ALTO • SUNNYVALE

CALIFORNIA

tinue as a consultant to the AF Scientific Advisory Board.

▶ As the new chief engineer of Radiation, Inc., **Parker Painter Jr.** will be responsible for the operation and administration of the entire Engineering Dept. He comes to the main office from Orlando, Fla., where he had been head of the Instrumentation Div.

▶ Borg-Warner's new vice-president for engineering and research is **Henry M. Haase,** with the company since 1955 and most recently assistant to the president. Two of Haase's major areas of responsibility will be the new Research Center in Des Plaines, Ill., and the Petro-Mechanics Research Div. in Los Angeles. He has held important executive positions with several other engineering companies.

▶ Eta Kappa Nu, national electrical engineering honor society, has dubbed **Jordon J. Baruch** of Bolt, Beranek & Newman, Inc., consulting engineers of Cambridge, Mass., the "Most Outstanding Young Electrical Engineer of 1956". Runner-up to Baruch, who is vice-president and director of new products development of BB&N, is **Robert B. Seidel,** president of Automatic Temperature Control Co. of Philadelphia. They were to receive their awards this month at the Winter Meeting of the AIEE.

▶ Another award, this one called the "Progress of New England Award", sponsored by the New England chapters of the Society for Advancement of Management, has gone to **Don R. Percival,** president and founder of Machinery Electrification, Inc., of Northboro, Mass. Percival was cited for his "outstanding achievement as a major executive of an industrial organization".

▶ **Jeanne Wentworth,** who played a major role in the management of the recent ISA show (CtE, Nov. '56, p. 25) as an associate of Showmanship, Inc., has been named vice-president of the Tabery Corp. show-running subsidiary.

▶ As vice-president and contract manager for Feedback Controls, Inc., **A. C. Brodie** takes on considerably broader responsibilities in the Waltham, Mass., company. He was with California-Texas Oil Co. in its Refining Div. before coming to Feedback Controls as assistant to the president.

▶ **R. J. Medkeff,** the new chief engineer of Penn Instruments, has been chief development engineer since last April, when he came to the Burgess-Manning division from Askania Regulator Co.

ABSTRACTS

Time—Constant Approximation

From "Response of Temperature-Sensing Element Analogs" by G. A. Coon, Taylor Instrument Cos. ASME 56-A-101.

In frequency response analysis of systems the frequency at which the open-loop system exhibits a phase lag of 180 deg indicates the speed at which the closed-loop system will recover from a disturbance. The higher the 180-deg phase-lag frequency, the faster the deviations reduce to zero.

The contribution of the temperature sensing elements in many industrial systems to the 180-deg phase lag is 30 deg or less. That is, the sensing element responds much faster to changes and disturbances than does the process. This is the premise used by Coon in establishing a low-frequency approximation of even the most dynamically-complicated sensing elements as a single time constant.

"This paper will show that the frequency response of many thermal systems can be represented adequately by a single time constant in the frequency range corresponding to 0 to 30 deg phase lag. For the systems studied, this time constant is equal to the thermal lag L (maximum time lag for a ramp input). Thus, in the region of 0 to 30 deg phase lag the transfer function of the sensing element can be approximated by 1(1+Ls). The lag L may be determined by experimental tests or by direct calculation. It is an easy matter to sketch the approximate frequency response.

"This low-frequency approximation is valid between 0 and 30 deg phase lag, which is precisely the region of interest when the thermal element is used in the control loop. By using the approximation, complicated thermal elements may be included in the loop with very little difficulty."

The low-frequency approximation is derived by analyzing a sensing element represented analogically by n unequal interacting time constants in series. The following results are valid up to the frequency where the approximation has a 30-deg lag. "For practical purposes the approximate and exact values are the same."

$$0.866 \le \frac{\text{approximate gain}}{\text{exact gain}} \gtreqless 1.00$$

$$0^\circ \le \text{approximate angle} - \text{exact angle} \le 3.1^\circ$$

After proving the general case, the

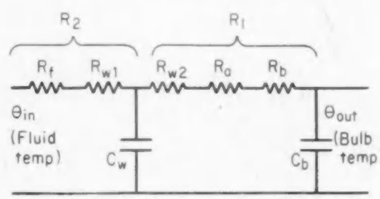
author meticulously investigates the approximation for single, two, and three time constants in series, for n equal noninteracting and n equal interacting time constants in series, and for liquid-filled and expansion-stem systems. Discussion of the system approximations in terms of physical entities enhances the value of the paper. The paper not only validates an important and useful approximation, but also shows various temperature sensing elements in terms of their transfer functions and the physical aspects (thermal resistances and capacitances) from which the transfer functions are derived.

Finding Response Graphically

From "Method of Presenting the Response of Temperature-Measuring Systems" by Robert Looney, Taylor Instrument Cos. ASME 56-A-102.

In this paper, a companion to the one presented by Coon (see abstract above), Looney adopts the validity of approximating temperature-sensing elements by a single time constant for phase lags up to 30 deg. He goes a step further, and shows how to find the actual time constant for a given measuring system. "This single time constant is dependent on the properties of the fluid whose temperature is being measured as well as the parameters of the system. Fortunately, the time constant turns out to be no more complicated than the sum of two numbers, one of which is dependent on the fluid properties and velocity and one which is dependent only on the parameters of the measuring system."

As an example, the author uses the case of a gas-filled tube system with the thermal bulb centered in a well. The figure represents the analogous



circuit for this system. Here, the lag L, equivalent to the approximated single time constant as proven by Coon in her paper, is:

$$L = R_2C_w + R_2C_b + R_1C_b$$

In terms of the physical properties of

the measured fluid and the measuring system, the time constant becomes:

$$T_e = \frac{1}{h_f}\left[\frac{C_w + C_b}{\pi D_o}\right] + |R_{w2}(C_w + C_b) + R_a C_b]$$

The first factors making up this single time constant is dependent on the fluid properties and velocity, the second dependent on the parameters of the measuring system and will be constant for small temperature variations. These factors, as brought out by the author in the form of governing equations suitable for calculations, depend on such properties as: film coefficient of heat transfer, thermal conductivity, well diameters and material, specific heat, density, and flow velocity.

Looney shows how the time constant can be found experimentally via graphical techniques. On log-log paper the graphs are straight lines, thus representing an equation of the form:

$$T_e = A/V^m + B$$

By changing the fluid velocity (and holding other conditions constant) several values of L (or T_e) will be obtained. "Then by subtracting from the total lag an arbitrary constant that yields a straight line on log-log paper for the difference versus velocity . . ." the value of the arbitrary constant B is found. The slope of the straight line equals m. These facts then define the total lag for any flow velocity when the other conditions are constant.

B remains constant for a given measuring system, while A depends on the physical parameters of the fluid being measured. The author shows, however, that by simple calculations (M values) the time constant found for one fluid can be converted to the time constant for another fluid. He tabulates some M factors to illustrate his case, and suggests that a more extensive tabulation, covering additional possibilities, may be a step toward finding time constants of a measuring element for numerous process fluids and toward establishing a standard means of specifying the approximation time constant.

In the experimental method, the total lag is found by frequency response techniques. "By means of curve-fitting a single-time-constant template to the frequency response diagrams for several known velocities, values for the single-time-constant approximation may be obtained.

". . . The presentation of approximating frequency-response data in this form [graphically as straight lines on log-log paper—Ed.] would be helpful to the user in selecting a temperature-measuring system with the least lag for his process." The author demonstrates this point by comparing the

results obtained with the gas-filled system. The mercury system has less lag at high water velocities while the gas system in the well has less lag at low water velocities and in air.

Numerical Control—Air View

From "Numerical Control of Machine Tools", a report by the AIA-AMEC-Numerical Control Subcommittee, by C. B. Perry and B. Gaiennie.

The "art" of numerical control is advancing rapidly, with about 350 companies doing development work in this field or in the associated field of data processing. There are several reasons for the many radically different designs of the available systems: the basic nature of the system, the function or purpose of the system, and the nature of the particular machine to be controlled. Some designs differ only because of patent considerations, or because the original design could not anticipate—for instance—the special requirements of skin milling. However, due to the activity of the Aircraft Industries Association, the Radio, Electronic & Television Manufacturers Association, and the National Machine Tool Builders Association, in exchanging information, techniques and performance data, many of the valuable features of the various systems are being widely adopted.

Completely unified numerical control systems are unavailable in the fullest sense, since no supplier offers numerical control, plus data processing, plus machine tool. Most machine tool builders are purchasing numerical control systems from electronics manufacturers, who can also furnish integrated computers—which must be ordered separately if a suitable computer is not available to the user. Some electronics manufacturers will sell to any builder, while others have exclusive arrangements with one.

About a year ago, the Airframe Manufacturing Equipment Committee of the AIA appointed the Numerical Controls Subcommittee to investigate tape control of machine tools, to prepare and process the necessary National Aircraft Standards, and to foster and protect the aircraft industry's special requirements. The scope of the committee's activities covers the complete numerical control system, from engineering drawing to machined and inspected parts. The systems investigated have been primarily continuous tool-path equipment, with 360-deg

machining in three axes. This means skin mills and profilers at present, and spar or bed and knee mills later on.

To study the field, a questionnaire requiring some 450 practical and technical answers was compiled, a standard AIA numerical test part drawing was devised, and a standard raw material blank was furnished. These were hand-carried to both foreign and domestic equipment suppliers. Thus, standardized, witnessed tests could be made, closely observed and carefully recorded.

How good is numerical control?

The results of the survey and evaluation to-date, based on machining the AIA test part, show some outstanding advantages for numerically controlled machine tools:

1. Present methods—transfer control

	Individual operation time, hours	Cumulative time, hours
Manual office work	3.	3.
Templates	97.5	100.5
Machining, tracer	3.6	104.1
Machining, boring	0.5	104.6

2. Numerical control method

Manual office paperwork	1.	1.
Data processing by computer	1.5	2.5
Machining, magnetic tape	0.9	3.4
Machining, boring, magnetic tape	0.1	3.5

3. Comparison between the two methods shows

Manual office paperwork, 66.6 percent reduction; data processing, 98.5 percent reduction; machining, 75.0 percent reduction; boring, 80.0 percent reduction.

The above test was run on a standard general-purpose machine converted to, not specifically designed for, numerical control. The piece, the first run, was machined on the same day the shop first saw the drawing. Twelve hours of inspection could not find cause to reject the part. If the average part can be made at only half of these percentage improvements, a real incentive for the private purchase of numerical control is indicated.

How are systems classified?

To permit a classification of functional systems, the subcommittee established the following categories:

1. By basic control function
   AIA Class I tape template—like a riveter

ABSTRACTS

AIA Class II cycle programmer—like a stretch press
AIA Class III point-to-point locators—like a lathe or drill press
AIA Class IV continuous tool path—like a skin mill or profiler

2. By basic electronic control concept
   Analog—varying voltages or voltage ratios
   Digital—countable discrete electrical pulses
3. By control storage data (inputs and outputs)
   Punched cards or punched tape
   Magnetic tape, multiple channel
   Numerous other means
4. By control code and/or language
   Decimal, binary, binary-coded decimal, etc.
   Voltage amplitude
   Electric pulses, pulse width, pulse phase
   Two state, non-return-to-zero
   Three state, return-to-zero
5. By machine tool and control
   High-speed, low-accuracy
   Low-speed, high-accuracy
   A combination of both (requested by subcommittee)
6. By manufacturer

How many machines are on order?

At present 140 numerically controlled skin mills and profile mills are on order. Of special interest is the fact that there are four types of control systems on these machines, none compatible at the part or machine tool level. The development of a medium—like multiple-channel magnetic tape—that has a bandwidth broad enough not to impose hardships on the best systems while allowing for future developments, is being promoted.

This lack of compatibility will considerably complicate the user problem during the first phase of application, but this is a small price to pay for the technological progress that is a direct result of the broad participation of manufacturers in these orders. By the middle of 1957, most aircraft plants will probably be operating numerically controlled machines.

Some anticipated problems

System evaluation and selection — There are a variety of control systems or parts of systems available for each application. Which one best fits the requirements of your plant?

System introduction—The efficient preparation of machine control intelligence requires the close cooperation of the following skills: machine parts planner, tool designer, cutting tool

ABSTRACTS

designer, lines layout or loft-data man, engineering liaison, and machine load planner. Your difficulties will depend to a large extent on the organizational separation that now exists in your plant between these skills.

Minimizing negative labor reaction—A problem that requires early attention, since these machines do not require the skilled machinists that were once the backbone of an efficient machine shop.

Maintenance – The installation of the equipment and its future maintenance will be only slightly more complicated than for conventional machines. But a well conceived and efficiently executed preventative maintenance program will be a must. Maintenance on a breakdown basis will not only be unwise but unworkable. Checking machine performance—rates of response, static and dynamic positioning accuracy, etc.—can probably best be handled by a test tape that will try the various operating characteristics of the machines to extremes. Running these tapes should be a regular part of the preventative maintenance.

Work interchangeability between machines—A difficult problem even between identical machines, it becomes more difficult with machines of basically different design, though they perform the same operations. Servo response rates and static and dynamic errors must be closely compatible. These are elements that must be considered when the machines are ordered.

Data processing—All of the combined intelligence contributed by the various skills listed above under "system introduction" must be brought together and synthesized into a series of electrical commands to a machine tool. This means that the organizational structure will probably have to be modified.

Quality control—The problems will be numerous and interesting. Since engineering drawings do not always define all of the requirements that a part must meet, could the inspector accept a part by surveying tape preparation, making sure that the tape represents an accurate numerical description of the required part? Then all that is necessary is to make sure that the operator uses the right cutter and that there is no system malfunction. Another approach suggested is automatic inspection machines.

Conclusion

The report concludes that there are no known or anticipated problems of

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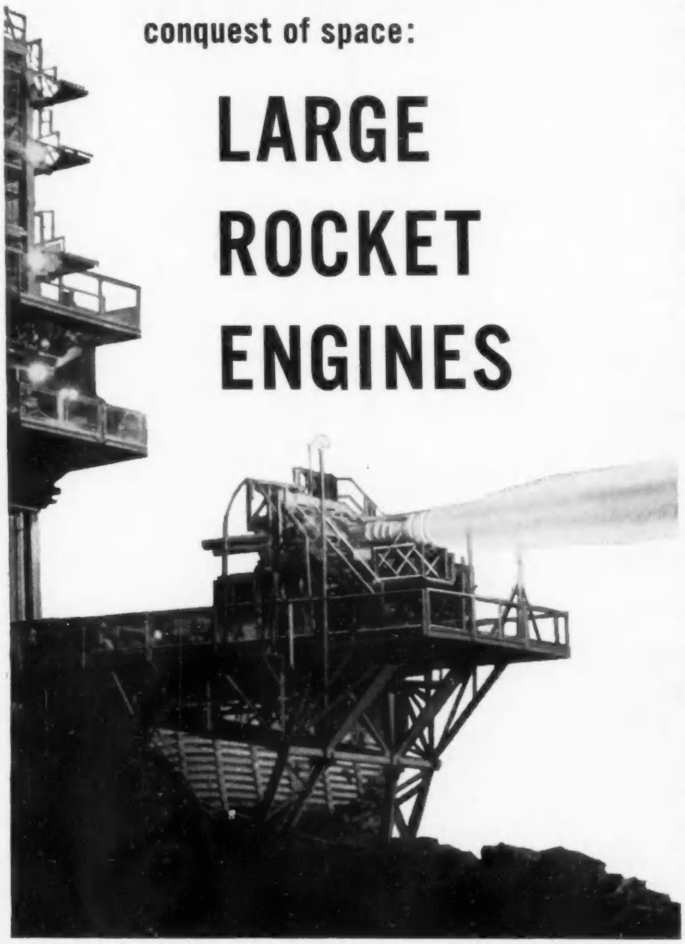

WILLIAM J. CECKA, JR., 35, aeronautical engineer, (Univ. of Minn. '43), was called from North American by the Air Force for experimental rocket work in 1944. On his return, he progressed rapidly: 1948, supervisory test job; 1950, group engineer, operations; 1953 engineering group leader; 1955, section chief of engineering test. Using our refund plan, he has his M.Sc. in sight.

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sufficient magnitude to jeopardize or delay the wide-scale application of numerically-controlled machine tools.

Briefly noted . . .

Superimposed Coding for Data Storage. M. Taube, Documentation Incorporated for Office of Naval Research, September 1956, 27 pages. (Order PB121345 from OTS, U. S. Dept. of Commerce, Washington 25. Price 75 cents.)

This report serves two purposes: it reviews attempts to achieve superimposition to eliminate the fixed field system of searching for only one code at a time, and it discusses multiple- and single-field types of superimposition coding of two or more codes in the same field to facilitate information searching on machine-sorted index cards. An appendix represents tables of dropping fractions for multiple- and single-field coding which can be used for searching any machine or catalog employing superimposed coding.

From "Conditions of Structural Stability in Feedback Control Systems" by M. A. Ayzerman, Moscow. Presented at the VDI/VDE Conference on "Modern Theories in Control Engineering and Their Usefulness", held at Heidelberg, Germany, Sept. 25-29, 1956.

Various criteria are given to determine the stability of automatic control systems in linear approximation (such as Hurwitz, Nyquist, and others). An investigation shows that the particular system considered is structurally unstable, i.e., even for arbitrary selection of its parameters the system cannot be made stable. This means that in order to attain stability the system's structure or block diagram has to be altered (e.g., by introducing new connections between its components). Using criteria given in the paper, (from the system's block diagram or from the drawing of the plant in question) it can be determined without any calculation whether the system is structurally stable or not. For structurally unstable systems it can be recognized from these criteria what kind of additional connections have to be introduced in order to make the system stable by appropriate selection of its parameters. Such criteria are indicated for single-loop systems with a derivative action and for systems with internal feedback loops. The work covered in this paper was done with F. R. Gantmacher.

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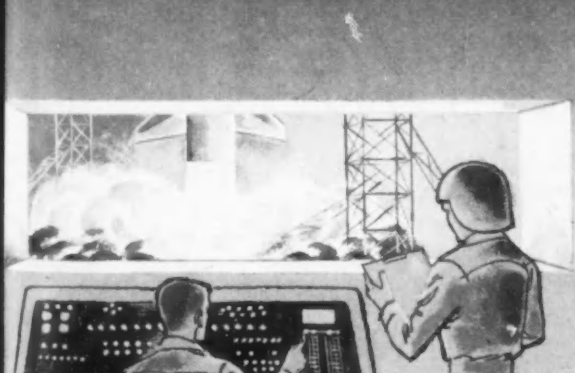

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NEW BOOKS

Describing the DDA

DIGITAL DIFFERENTIAL ANALYZERS. George F. Forbes, senior engineer, Litton Industries. Part I. ELEMENTS, pp. 1-48; Part II, APPLICATIONS, pp. 49-154; plus appendices. Published by George F. Forbes, 10117 Bartee Ave., Pacoima, Calif. $7.50.

The Bush-type analyzer solves differential equations by mechanical-electrical means. In it integration is accomplished by rotation of mechanical parts, and the solution is displayed as one or more continuously-plotted curves. Installations range from large room-size to desk-size models.

The digital differential analyzer solves problems by electronic-magnetic means. Here, integration is effected by use of numerical registers recorded as pulses on a rotating magnetic drum, and is carried out stepwise as in solving by finite differences. Installations range from small room-size to desk-size models.

Although the two types are analogous in many ways, the construction, principles of operation, and uses of the DDA are such that "as a generalization, any problem capable of being solved on the Bush analyzer can be done on the DDA". For this reason the DDA has a considerable potential use as a facile numerical tool in systems research and design. As the book under review is the only one in print which gives a detailed account of the DDA, it is of obvious value to those who would obtain knowledge of this computing device.

The author's emphasis is on the mathematical capacities of the equipment rather than on giving explicit details of its operation. The subjects covered in Part I, noted below, require a knowledge of ordinary calculus and simple differential equations. Part II requires the kind of understanding of advanced calculus that could be obtained from a one-year course.

Part I covers the digital differential analyzer, schematic systems and scaling, generation of algebraic and transcendental functions, adders and servos, normalization, multiplication and division, and Amble's method for generating dx/y.

Part II concentrates mainly on applications: generation of miscellaneous functions, simultaneous algebraic equations, accuracy of the DDA, limiters and discontinuities, functions of several variables, partial differential

equations, conformal mapping, curve analysis, and Shannon's theorem.

Litton Industries, with which the author is associated, publishes an irregularly-issued house organ, *DDA Summation*, that reports on "digital differential analyzer methods in computation and control". Subscriptions can be obtained (gratis) by writing to the company at: 336 North Foothill Rd., Beverly Hills, Calif.

Thomas J. Higgins
Madison, Wis.

Confined but Enormous

INTERNATIONAL DICTIONARY OF PHYSICS AND ELECTRONICS *Published by D. Van Nostrand Co., Inc., Princeton, N. J.,* 1956, $20.

The monumental task facing a group of 15 contributing editors, headed by Bryn Mawr College's Walter C. Michels, was to bring together under one cover the common (and not so common) physics terms appearing in the fields of mechanics; liquid, solid, and gaseous states of material; heat and thermodynamics; acoustics, optics, electricity and electronics; meteorology; atomic and nuclear physics; mathematical physics; quantum mechanics, and relativity.

This dictionary is the result. It contains over 1,000 pages with an estimated 13,000 to 15,000 definitions in the scientific fields listed above. The definitions selected, the preparation of the text, the method of cross-referencing terms, and the introductory material on units and dimensions reflect the competence of the editors.

Briefly, their approach to the organization of the dictionary was this:

- where possible, use definitions established or recommended by professional groups
- define terms to include laws, relationships, principles, equations, and concepts; describe widely-used instruments and apparatus
- make the book useful to those without extensive mathematical background by defining terms explicitly and discursively
- signify, by use of bold type, those definitions using words or expressions that are themselves definitions as a clue to additional information on the subject
- supplement the definitions with illustrations (over 300 included)

The book is helpful in finding the meaning of scientific terms encountered for the first time, for check-

ng the spelling of words not found in desk-type English-language dictionaries, and for clarifying concepts of terms already known. The value of having it near at hand during working hours can not be overstated [our editorial staff uses it frequently. Ed.], while keeping the book at home enables Scrabble-playing wives to beat the girls at the every-other-Thursday-night tourney with words such as amagat, dendrite, ergon, phon, and phot.

Light Under a Bushel

THE PUSHBUTTON WORLD—AUTOMATION TODAY. *Edited by E. M. Hugh-Jones. 158 pp. Published by The University of Oklahoma Press, Norman, Okla. $3.75.*

There seems to be just one really "new voice" in this otherwise too familiar collection of essays on automation. That is not to say that competence is lacking. It is not; all the writers know their fields and talk about them with assurance. It is just that one contributor, H. R. Nicholas, national secretary of the Metal & Engineering Group of the Transport & General Workers Union of Great Britain, offers something unique, while the other six do not. However, what Nicholas has to say is so outstanding that it alone is worth the $3.75 price of admission.

From the title of his essay, "The Trade Union Approach to Automation", one would think that here is an item that cannot be read outside its British context. Such thinking would be wrong. Nicholas might be confining himself to Great Britain, but his ideas are universal. Not only is his piece the longest in the book, but it is the most far-reaching. In talking about trade unions and the worker, he recognizes an obligation to touch on many of the other fields besides labor which have been concerned with existence in a scientific society, and in doing so penetrates deeper than most writers who have gone before him.

Take his thinking on bringing the worker in on plans for retooling a plant for automatic control: "It would be true to say that whatever advances have taken place in recent years, however freely employers and unions may consult at national level, we have only touched the fringe of true joint consultation. I know of one factory where an advanced automatic process was to be introduced, and the management gave no indication of its intentions to the workers until the last moment. It was not until the men had taken action which they con-

sidered was best calculated to safeguard their interests that it was explained that the new method would not put men out of work but would create the need for additional labor. How short-sighted a management policy that was! The whole unfortunate affair could have been avoided by consultation and by seeking co-operation of those affected, men capable of thinking and understanding, and who have a vital stake in the industry. When will some employers realize that, although men must work to maintain themselves and their families, they are also conscious that there is something more to a job of work than performing a task which entitled them to a wage packet week by week? . . ."

Automation, says Nicholas, will displace the worker in more ways than one. That is, it is not only possible that he will be displaced out of a job, but he may also be displaced *in* his job, and the effects of the latter displacement may be just as hard on him, for no work or erratic work means the same thing to a man who wants to get along with his society. Says Nicholas: "It is becoming increasingly apparent that, in our manufacturing industries, managements who embark upon exceedingly heavy expenditure to equip their factories with automatic devices are anxious to get everything they possiblly can out of their machines for as many hours as possible. More and more we may have to face up to the introduction of shiftworking methods. . . .

"There is little doubt that there will have to be fresh thinking about our established wage structures, if we accept that we cannot think in terms of the past in an automation age. . . . The introduction of automation means that the rate of production will be determined by the machine and this development demands a new approach to the question of earnings as well as to grading problems. We may have to think in terms of high standard rates as distinct from low basic rates plus piece-work earnings. In addition, incentive schemes cannot be entirely eliminated merely because at one point of production automation has been introduced. . . .

"It may well be that the unions themselves will have to examine closely their own structures. Existing lines of demarcation may disappear, crafts may become integrated, new ones may be born, the causes of many disputes between unions may be completely eliminated and others intro-

duced. Experience alone will show best how these problems can be dealt with. Difficulties have been faced before and overcome. The trade union movement is no more complicated than industry itself, although it is by no means scientifically planned. Neither are many other of our great institutions. They meet the needs of the times and beyond question, in the future as in the past, will adjust themselves to meet those needs. . . .

"One of the consequences of automation could be a redundant labor force in one place and a labor shortage in another. This throws up the problem of re-deployment of labor and the results can be readily appreciated. Apart from the question of training men, perhaps of advanced age, for work which is new to them, there is the question of finding homes for them and their families, the uprooting of their established traditions, the breaking away from all their community interests to begin life anew in a strange place, the interference with children's education, maybe the breaking up of the family. The new towns have experienced many teething troubles in these matters and we should be able to profit by their experience.

"If it is not possible to take displaced people to new industry, can industry be taken to the people as some firms are doing already? Will we need to establish Development Areas in those places normally regarded as safe areas? To what extent would government aid be available to assist industry and workers in resolving issues of this nature? . . . ."

And finally, but welcome indeed, is this thought: "More detailed study, particularly by national and local government, must be given to the need to develop social interests among young people, who in future may have more time on their hands than they have now. They must be given a sense of responsibility to the community, a greater appreciation of books, music and the arts. They must be shown that relaxation extends beyond the street corner or the television set. They must be taught at school the things most of us discover afterwards—among other things, the meaning of local and national government, the laws and regulations which control their lives, the stability which the growth of the trade union movement has given to our industrial structure, so that when they enter into the work-aday world they will realize that they have a part to play which extends beyond interest in the size of the wage packet or the hours of labor."

WHAT'S AHEAD: MEETINGS

JANUARY

American Institute of Electrical Engineers, Winter General Meeting, Hotel Statler, New York Jan. 21-25

FEBRUARY

Instrument Society of America, New York Section, Midwinter Conference (Aircraft Instrumentation), Garden City Hotel, Garden City, Long Island, N. Y. Feb. 7

Institute of Radio Engineers, Transistor and Solid State Conference, University of Pennsylvania and Bellevue-Stratford Hotel, Philadelphia, Pa. Feb. 14-15

Western Joint Computer Conference, Hotel Statler, Los Angeles Feb. 26-28

MARCH

American Society of Mechanical Engineers, Nuclear Congress, Convention Hall, Philadelphia March 10-16

Institute of Radio Engineers, 1957 National Convention and Exhibition, N. Y. Coliseum and Hotel Waldorf-Astoria, New York March 18-21

Nineteenth Annual American Power Conference, Hotel Sherman, Chicago March 27-29

APRIL

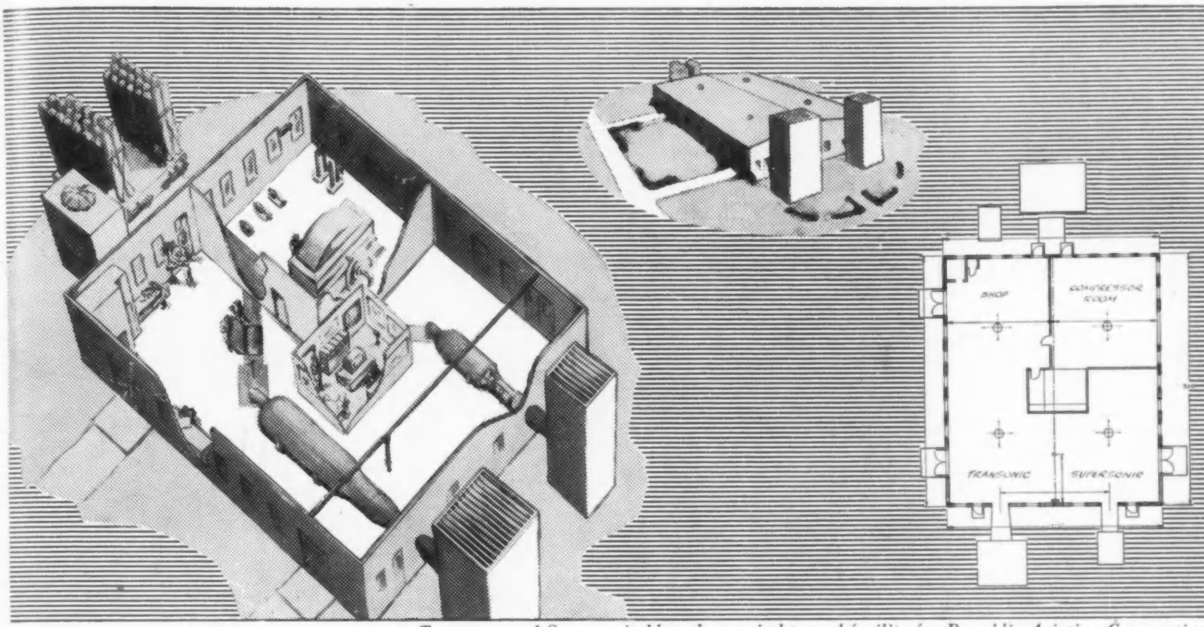
American Society of Mechanical Engineers, Spring Meeting, Dinkler-Tutwiler Hotel, Birmingham, Ala. April 8-10

Instrument Society of America, National Nuclear Instrumentation Conference, and Third Southeastern Regional Exhibit, Atlanta Biltmore Hotel, Atlanta, Ga. April 10-12

Second National Simulation Conference, and Ninth Southwestern Institute of Radio Engineers Conference and Electronics Show, Shamrock Hotel, Houston, Texas April 11-13

American Society of Mechanical Engineers, Instruments & Regulators Div. (IRD) Third Annual Conference, Northwestern University, Evanston, Ill. April 22-24

Second National Industrial Research Conference, "Research for Profit", sponsored by Armour Research Foundation of Illinois Institute of Technology, Conrad Hilton Hotel, Chicago April 24-25



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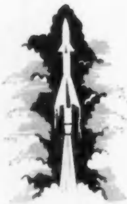
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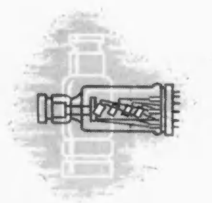
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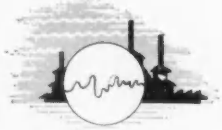
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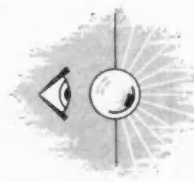
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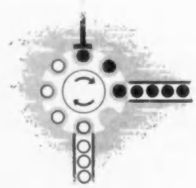
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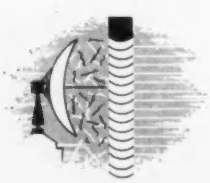
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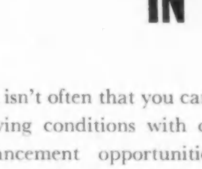

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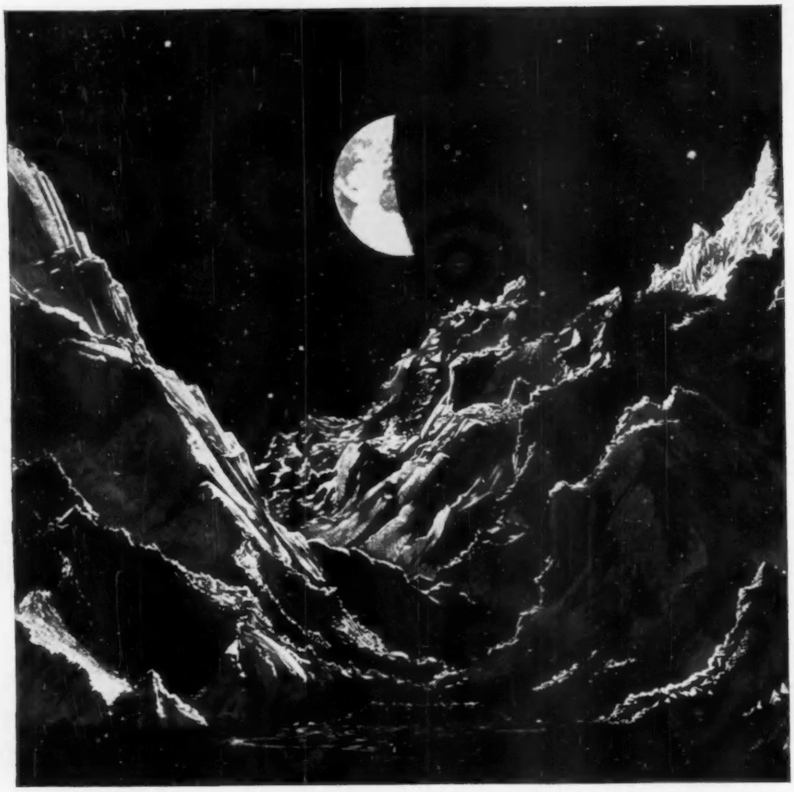

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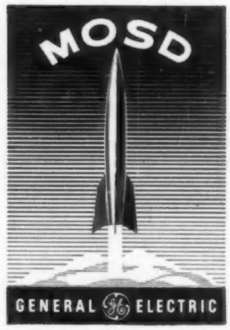

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